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ABSTRACT

These hearings focused on the National Science Foundation's (NSF) proposed program and budget. Testimony of witnesses, prepared statements, discussions, and supporting documentation (including hearings summary) are provided. Among the issues, areas, and topics addressed were: (1) relevance of NSF's mission to presidential goals; (2) science and engineering education, considering NSF responsibilities for graduate education, NSF role in pre-college programs (evolution of NSF pre-college activities and objections to NSF's perception of its limited role in precollege science education), and NSF undergraduate science education programs (augmenting teachers' salaries and matching programs, and use of computers in education); (3) programs in the astronomical, earth, and ocean sciences; (4) research instrumentation (considering federal aid, industrial funding, NSF relationship to National Technical Information Service, university views of inadequacy of instrumentation and responsibilities for funding instrumentation); (5) new management plan for the Directorate for Scientific, Technological, and International Affairs; (6) support for behavioral and social science research support programs; and (7) support for information sciences research (including research that warrants attention, NSF involvement in computer networks, need for coordination of information sciences research in NSF). The issue of transferring Environmental Protection Agency research to NSF was also discussed. (JN)

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1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

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HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

FIRST SESSION

ON

H.R. 2066

FEBRUARY [illegible] MARCH 1, 2, 10, 1983

[No. 21]

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Committee on Science and Technology

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1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, FEBRUARY 23, 1983

House of Representatives,
Committee on Science and Technology,
Washington, D.C.

The committee met, pursuant to other business, at 11:35 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua, chairman, presiding.

Present: Representatives Fuqua, Walgren, MacKay, Gregg, McGrath, Skeen, Bateman, and McCandless.

Mr. Fuqua. Today we are continuing full committee hearings on research and development in the Federal Government's budget for fiscal year 1984. We will hear from Dr. Edward Knapp, Director of the National Science Foundation.

I am quite pleased that the National Science Foundation's proposed budget for fiscal year 1984 of $1,292.3 million represents an increase of $195.1 million or 18 percent, over the currently planned level for fiscal year 1983. This total provides $1,250.7 million for research and $39.0 million for science and engineering education activities of the Foundation. I am delighted with the strong support for basic research provided by this budget.

Although I am generally pleased with the Foundation's budget, there are several details which will receive further consideration as our authorization hearings proceed. In particular, there has been what I believe is an insufficient increase in science education. The amount requested for the Foundation's education activities is less than one-half of the amount spent in fiscal year 1981.

H.R. 1310, a bill regarding engineering, math and science education developed by this committee in conjunction with the Education and Labor Committee, was reported by the Science Committee yesterday. This bill will assist in closing the gap created by the fiscal year 1983 budget reductions and the fiscal year 1984 proposal. However, the support provided in this bill is not adequate to meet the urgent science education needs of the Nation.

With regard to the research components of the Foundation, the administration has stressed that their fiscal 1984 programs are selectively targeted to areas likely to have the greatest long-term impacts on new technologies. I agree in principle with this philosophy. However, I am concerned that they appear to be understating the contribution of the behavioral, social and information sciences to the effective utilization of those new technologies for the public good.

In past years we have achieved a good balance between basic and applied research, and we have sought to achieve a degree of funding stability which many in the research community have requested. We must ask if the changes contained in the present proposals are sound and whether the proposed budget levels for 1984 should be sustained in future years.

Before proceeding, I want to take this opportunity to welcome Dr. Knapp to his first public appearance before the committee as Director of the National Science Foundation. Dr. Knapp, I am very pleased with your appointment and look forward to working with you.

Dr. KNAPP. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Walgren, did you have a statement to make?

Mr. WALGREN. I have one that probably could go in the record at this point. Just carry on from there.

Mr. FUQUA. Without objection, the statement of Mr. Walgren will be placed in the record.

[The opening statement of Mr. Walgren follows:]

STATEMENT OF
CONGRESSMAN DOUG WALGREN
NSF POSTURE HEARING

FEBRUARY 23, 1983

I AM HAPPY TO JOIN WITH YOU, MR. CHAIRMAN, IN WELCOMING DR. KNAPP. I LOOK FORWARD TO HEARING HIS TESTIMONY TODAY AND IN THE NEXT FEW WEEKS AS THE SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE HOLDS HEARINGS ON IMPORTANT AREAS OF NSF'S PROPOSED PROGRAM AND BUDGET.

LAST WEEK THIS COMMITTEE HEARD DR. KEYWORTH OPEN THIS YEAR'S SERIES OF POSTURE HEARINGS BY PRESENTING THE ADMINISTRATION'S PROGRAM FOR FEDERAL R&D IN THE COMING YEAR. WHILE I AM SURE THAT THERE WILL BE DEBATE IN THE CONGRESS OVER THE PROGRAMS AS PROPOSED, AND MOST CERTAINLY SOME CHANGES WILL BE MADE, I CANNOT HELP BUT BE PLEASED THAT THE ADMINISTRATION IS FINALLY, IF BELATEDLY, ADDRESSING SOME OF THE PROBLEMS THAT HAVE BEEN OF CONCERN TO THIS COMMITTEE. I AM REFERRING SPECIFICALLY TO THE PROBLEMS IN UNIVERSITY INSTRUMENTATION AND IN SCIENCE AND MATH EDUCATION. I AM ALSO PLEASED THAT NSF APPEARS TO BE ASSIGNED A LEADING ROLE IN WORKING ON THESE PROBLEMS. I SEE THAT THE $180 MILLION THAT NSF PROPOSED TO SPEND ON RESEARCH EQUIPMENT AND INSTRUMENTATION WILL BE 45% OF THE $400 MILLION TO BE SPENT BY THE GOVERNMENT FOR THIS PURPOSE IN 1984.

ON THE OTHER HAND, I CANNOT HELP BUT BE DISAPPOINTED THAT THE FOUNDATION INCREASED THE PRECOLLEGE TEACHER IMPROVEMENT PROGRAM BY ONLY $5 MILLION. LOOKING AT IT ANOTHER WAY, THIS INCREASE AMOUNTS TO LESS

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THAN 3% OF THE TOTAL INCREASE IN BUDGET PROPOSED FOR THE FOUNDATION. THE CONTRAST BETWEEN DR. KEYWORTH'S TESTIMONY AS TO THE IMPORTANCE OF THE SCIENCE AND MATH EDUCATION PROBLEM AND THE SMALL INCREASE IN ADDITIONAL RESOURCES ALLOCATED TO PROGRAMS TO SOLVE THE PROBLEM IS STRIKING. AS THE OLD SAW GOES "ACTIONS SPEAK LOUDER THAN WORDS".

IN THE COMING AUTHORIZATION HEARINGS WE WILL EXPLORE THIS ISSUE FURTHER, KEEPING IN VIEW THE SCIENCE EDUCATION BILL REPORTED BY THIS COMMITTEE YESTERDAY. WE WILL ALSO LOOK AT THE CURRENT UNIVERSITY INSTRUMENTATION SITUATION AND REVIEW FUTURE DIRECTIONS OF OCEANOGRAPHIC AND ASTRONOMICAL RESEARCH AND NSF'S ROLE IN THESE AREAS. IN ADDITION, WE WILL CAREFULLY LOOK AT PRESENT PROGRESS AND FUTURE PROJECTIONS IN THE BIOLOGICAL AND BEHAVIORAL SCIENCES AND THE SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS DIRECTORATES.

NOW, MR. CHAIRMAN, I AM PLEASED TO HEAR WHAT DR. KNAPP HAS TO SAY.

Mr. FUQUA. Dr. Knapp, you may proceed.

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. KNAPP. Mr. Chairman, members of the committee, this is my first appearance before you, and it is indeed a pleasure for me to be here today.

The 3 months which have passed since I was appointed Director of the Foundation have been exciting ones for me personally and for NSF. I believe you will share my excitement as you hear the details of the Foundation's proposed programs for fiscal year 1984 in this and forthcoming hearings.

Today I would like to talk about basic research and its place in the Nation's science and technology enterprise. Then I will describe the National Science Foundation and its role.

I will attempt to give you a feeling for the broad range of research supported by NSF and its importance to the technological knowledge base and to the training of the future engineers, scientists, and technicians who will contribute so much to the universities, Federal laboratories and industries.

Finally, I will present some of the highlights of NSF's proposed budget for fiscal year 1984 and describe some of the new directions it contains. I will not go into detail today about specific funding levels for the dozens of programs in the NSF budget, but I do look forward to discussing the budget in greater detail in the subcommittee hearings.

It is timely for us to consider, for a moment, the contribution of basic research to society and how science plays an important part in addressing many of the current and long-term concerns of the Nation.

Regardless of our profession or walk of life, we all have a continuing stake in keeping new scientific ideas flowing from research. We hear a lot these days about the need to preserve the U.S. competitiveness in science and technology and to provide the personnel to carry this country into a new technological age.

In a recent speech to the Massachusetts High Tech Council Forum, the President underscored the Government's policy toward research:

> We will propose unprecedented increases in fundamental research because it offers essential support for our industries and our defense needs. And we will channel this research into the most promising areas—those most likely to extend the benefits of American science expertise to industry.
>
> As you know, research is the wellspring of ideas that lead to new technologies, such as the transistor and the laser. And it is also the key course for the highly trained scientists and engineers that . . . we will need to lead us into the next century.

The fundamental research that NSF supports makes a central and creative contribution to the economic health and vitality of this Nation. Without a strong long-term research effort, the vitality and innovativeness shown by the country's high-tech economy would quickly fade.

Over the years, a consensus has been developed on the value of long-term fundamental research. And we at the National Science Foundation have a major role to play in helping to insure a strong and balanced Federal effort in supporting such research.

The Foundation was established in 1950 in recognition of the important contributions made by science and technology during World War II and the desire of the Government to continue these contributions into the post-war period.

NSF occupies a unique place in the research community and among Federal agencies that sponsor research. Let me explain why this is so.

The staff of the Foundation does not conduct research. NSF funds, in the form of grants and contracts, support scientists and engineers outside the Government, the majority of whom are employed by universities and colleges. The creative research ideas come from the scientists themselves; decisions on project support are made by NSF program officers in a competitive process using advice from outside experts called peer reviewers.

We do this through several mechanisms. Last year NSF obtained the assistance of nearly 50,000 individual scientists, engineers and educators to help select the highest quality proposals for support. These advisers contribute their time and ideas because they believe it is important, and their work is the key to the Foundation's ability to conduct business with an overhead of less than 6 percent of NSF's total funding. We are proud that NSF spends a smaller percentage of its funds to conduct its business than do most private foundations.

I believe that the competitive nature of the Foundation's award process is one of the great virtues of the American scientific system. NSF concentrates on supporting excellence—the most promising work on the frontiers of science—from researchers all across the Nation.

It is interesting and illuminating to examine the place of NSF in the total Federal effort in research and development. The fiscal year 1984 investment in research and development by the Federal Government is estimated at about $46 billion. The major R&D funding agencies are the Departments of Defense, Energy, Health and Human Services, including NIH, and NASA. With the $1.3 billion budget proposed for the Foundation's responsibilities, the NSF is not a leading factor in the total investment for research and development by the Federal Government. But in the Federal investment for basic research, the Foundation plays a significant role in insuring the health and vitality of the Nation's research enterprise.

Historically, the Nation's colleges and universities have been the institutions in which most long-term, fundamental research work is carried out. In the support of basic research at universities, the Foundation accounts for about three-tenths of all Federal funding and trails only the National Institutes of Health, which concentrates its funding on health-related research.

While NSF supports research across all disciplines, the level of its involvement in support differs by field. For example, at universities and colleges, NSF provides two-thirds of all Federal obligations for the conduct of basic research in the geosciences. And NSF provides virtually all of the Federal support in ground-based astronomy. Over one-half of all Federal obligations for the conduct of basic research in the mathematical and physical sciences is provided by NSF. And over one-third of all Federal obligations for the conduct of fundamental engineering research is supported by the Foundation.

I should add that NSF does not support clinical research or work in the development part of the R&D spectrum.

Administration and congressional decisions on the NSF budget, probably more than those of any other agency, reflect explicit science policy choices that directly affect a large portion of the academic scientific community. Thus there is considerable interest in that community about policy directions as they are reflected in NSF's budget.

The President, in his state of the Union address, said, "This administration is committed to keeping America the technological leader of the world now, and into the 21st century."

How does NSF contribute to that commitment? In my view, NSF's budget is a strong, well-balanced request; one that will support and continue a great deal of very exciting research. The fiscal year 1984 budget request is approximately $1.3 billion, an increase of 17.8 percent above the fiscal year 1983 current plan, and features an 18.3-percent increase in the support of basic research.

It encompasses Presidential initiatives to encourage the most outstanding young scientists and engineers to pursue academic research careers in areas of particular scientific need and opportunity, and to help restore quality to the teaching of science and mathematics in the secondary schools.

The requested rate of growth in the Foundation's budget and the emphasis contained in this budget, reflect three concepts.

First, the importance of basic research in laying the groundwork for long-term economic growth, and providing a foundation for the technologies on which national security and other goals depend.

Second, the need to revitalize the research base in the colleges and universities and to insure their continuing ability to produce "world class" scientists and engineers in the years ahead.

And third, the importance of quality education in science and mathematics in the secondary schools to continuing U.S. technological and economic leadership in the world.

The context within which this budget was developed centered on the President's determination to provide sufficient investment in R&D to assure the long-term health of the economy. In his appearance before you earlier this month, Dr. Keyworth mentioned that three criteria were used in developing the fiscal year 1984 R&D budget. I have already addressed one of them: The appropriateness of the Federal role, and the Foundation's role, in the support of research.

The second criterion is concerned with the intellectual promise of a field of research. NSF consults widely to determine areas ripe for intellectual advance and chooses to increase support for some areas on that basis. Examples include mathematics, chemistry, elementary particle physics, and astronomy.

The third of Dr. Keyworth's criteria, pertinence, is addressed in the Foundation's emphases on areas of potential importance to future technological development, such as engineering, computer research, plant biology, Earth sciences, and materials research. The criteria of intellectual advance and pertinence are not mutually exclusive, of course, and all the fields I have mentioned meet both.

Within this context the Foundation supports research activity in a variety of ways: grants to individual scientists; large national research facilities in some fields such as astronomy and atmospheric sciences; provision of instruments used by individuals and by teams of investigators; participation of graduate science and engineering students in research projects; numerous cooperative research activities conducted under bilateral agreements with other nations; and special efforts to increase the role of women and minority scientists and engineers in research.

The request also includes $39 million for science and engineering education, including support of the NSF graduate research fellowships and of Presidential initiatives to strengthen science and mathematics teaching in the secondary schools. In a moment, I will share with you my views on science and engineering education.

As far as emphasis in research programs is concerned, Dr. Keyworth has stated:

> "Over the past 20 years, our academic institutions have grown shabby. With few exceptions they have become less and less attractive places to pursue research. Equipment and instrumentation are not as good as that in national labs, or in many industries. Somehow we have arrived at the indefensible position of creating the poorest climate for research in the place that ought to have the best."

First, across all NSF programs, the fiscal year 1984 budget request recognizes the need to improve the quality and availability of research instrumentation and equipment. The funding will increase the productivity of researchers and enable them to investigate new, exciting areas in fields such as biology, astronomy, engineering, Earth sciences.

Second, including graduate students and postdoctoral fellows in NSF research projects is critical to their training in research. These are the individuals on which future excellence and competitiveness in science, engineering and new technologies depends.

These two areas, instrumentation and trained personnel, were discussed extensively by Dr. Keyworth before this committee. As he said, they have been severely eroded in the past 15 years and must be repaired. NSF proposed budget for fiscal year 1984 begins this rebuilding process.

I will not go into details of the requested budget for specific disciplines and programs. You have the details in the tables attached to my written statement, and we will be discussing them in future hearings. But I would like to take a minute to give you the flavor of some of NSF's program emphases.

The physical sciences budget, which accounts for close to one-third of NSF's research budget, places emphasis on the mathematical sciences and on materials research. Support will continue for mathematics research institutes that provide greater interaction among mathematicians. The budget also provides increased support for graduate students, postdoctoral scientists, and young faculty researchers.

NSF's emphasis in materials research permits a substantial strengthening of facilities and instrumentation within this field. Materials science is an area of research in which the United States now holds a decisive world lead and one where great advances appear imminent.

In engineering, NSF will support research that underlies critical technologies and processes in the computer, electronics, and chemical industries. NSF's program stresses such areas as robotics, microelectronics, biotechnology, and automated manufacturing—key areas that can contribute to productivity and economic growth.

In addition, NSF is responding to the current shortages of engineering faculty and advanced graduate students by proposing major increases in the support of young engineering faculty.

Primary emphasis in the biological sciences is placed on enhancing research in plant biology to develop further understanding of the way plants synthesize carbohydrates and the role of cell membranes in nitrogen fixation.

I should mention that a remarkable achievement involving nitrogen fixation was announced last month. Nitrogen is a paradox. It is an essential and plentiful plant nutrient but it is inert and unavailable to most plants. It would be unavailable to all plants except for bacteria that convert nitrogen to ammonia which plants are able to absorb. The process is controlled by a set of genes in the bacteria.

Recently these bacterial genes were inserted into alfalfa cells and made to function there. The result was the visible formation of nodules, the tiny vesicles within which nitrogen fixation occurs, so the alfalfa cells could use the nitrogen.

Since these genes presumably can be inserted in other plants, this advance signals a new frontier for plant biology and an expansion of the world's future food supply.

Let me turn to another scientific field. Astronomy is an observational rather than a laboratory science—the phenomena observed are on a cosmic scale, and there is a need for large and expensive instruments and national facilities. In fiscal year 1984, NSF will support design studies for the "Very Long Baseline Array," an instrument comprising 10 radio telescopes placed throughout the United States.

Let me make it clear that NSF is not proposing contruction of this facility in this budget. The studies being funded will provide the information necessary to consider the VLBA in future budgets. When finished, this facility would be the largest and most powerful instrument of its kind in the world. With its extraordinarily high resolution, astronomers will be able to see the centers of distant, giant galaxies and quasars. Because these studies go hand in hand with so much state-of-the-art technology, modern astronomy adds significantly to the Nation's pool of scientifically and technically trained personnel.

Even more, it expands the understanding of the universe and, therefore, the human imagination. Perhaps that is why astronomy is the oldest of the sciences and why there is today such a large popular interest in it.

Many of you are familiar with NSF's deepsea drilling program that has contributed so much to the understanding of the motions of the Earth's crust, and with the much discussed question of whether to replace the existing drill ship, the *Glomar Challenger,* with another, the *Glomar Explorer.* Not long after I became Director, I decided that a new look at this issue was in order. To do so, NSF established a special advisory committee composed of ocean scientists to recommend a long-term program in Earth crustal dynamics, with special emphasis on the role of ocean drilling. That committee met earlier this month. Based on the discussion at that meeting, it appears the committee will recommend that NSF continue to support ocean drilling, preferably with a leased commercial drill ship.

Because of recent changes in oil exploration business, it appears that a ship now can be leased at a much lower cost than conversion of the Explorer. Many aspects of this idea need to be thought out. When the committee makes its final report, I will consider it and discuss it with the National Science Board, with Dr. Keyworth, and with the Congress.

Now let me mention an important national effort, the U.S. Antarctic research program. In February 1982, the President issued a decision memorandum which stated that the Foundation is to continue to budget for and manage the entire U.S. national presence on the Antarctic Continent—and that this program is not to be funded at the expense of other National Science Foundation programs.

NSF efforts in fiscal year 1984 will entail support for Antarctic research projects in several fields of science, for improvements to the facilities critical to the conduct of a safe and effective research program, and for the maintenance of an active and influential U.S. presence there.

In addition to the programs of support for work in various research disciplines, the Foundation has a number of other programs which cut across the concerns of all disciplines and have an important bearing on their health and vitality. These programs address several topics: Research and scientific education at predominantly undergraduate colleges; participation of women and minorities in research careers; research under various international bilateral agreements; cooperative research projects among scientists and engineers in industry and those in universities; and research conducted by small businesses.

I now turn to NSF support of science and engineering education. This subject is of deep concern to me. I know it is of concern to you. I strongly believe that NSF has a responsibility in this area, and I know that the administration, this committee, and the Congress as a whole agree. Let me outline my view of the nature of the NSF responsibility.

The Foundation's role in science and engineering education is quite different from its role in research that I outlined earlier. The ultimate responsibility for education, especially on the elementary and secondary level, has always belonged to the States and local communities. About $200 billion a year is spent on education in this country, to which the Federal Government contributes less than a tenth. Federal agencies other than NSF play a significant role. This is especially true for the Department of Education, whose fiscal year 1984 budget request is about $13 billion. Seen in this light, the resources available to the Foundation are so miniscule that they must be used carefully and selectively.

The basis for NSF's involvement with science and engineering education is twofold: First, as noted by the National Science Board in August 1981, "* * * the Foundation has a special role and responsibility in supporting the long-term development of a strong human resource base in science and engineering."

Second, the Foundation has available to it especially strong connections with research scientists and engineers. At the university level, the Nation is experiencing shortages of qualified faculty in certain areas of engineering, computer science, and Earth sciences. Many students are stopping their formal education at the baccalaureate and master's degree levels to take attractive positions in industry. The pool of candidates for doctorate degrees and for academic positions is reduced.

To address this problem, NSF's fiscal year 1984 request includes funds to initiate a program of Presidential young investigator awards. This program aims to make university faculty positions more attractive to the most promising young faculty members by providing research funds for up to 5 years. Up to 200 awards a year will be given, with matching funds required from private industry.

Additionally, research programs across the Foundation will place an emphasis on expanded support for graduate students as research assistants on NSF projects. In fiscal year 1984, there will be some 10,000 graduate students working on research projects in this country. These are in addition to the 1,390 predoctoral fellowships that the Foundation will support.

At the undergraduate level, the fiscal year 1984 request contains funds for a new research participation program directed to the large number of non-Ph. D. granting colleges. These colleges provide many of the graduate students for the research universities. NSF will support research activities by undergraduate college faculty at major academic institutions and governmental research facilities. These activities will involve some of the colleges' more promising students. The program will also provide the necessary equipment at the smaller institutions.

At the precollege level, we should never lose sight of the fact that the mathematics and science instruction received by students in elementary and secondary schools underpins future research and technology. It is important for the economy; it is the bedrock of national security; it is essential for all citizens in a technological age. Yet there is broad agreement that secondary school science and mathematics education in the United States is inadequate to meet the growing needs for scientific and technical skills in the Nation's work force.

And the most critical factor in this situation is the shortage of teachers who have adequate backgrounds in the subjects they are teaching.

Accordingly, the Foundation will continue in fiscal year 1984 two efforts to be initiated in fiscal year 1983. First, Presidential teaching excellence awards in science and mathematics will provide national recognition for approximately 100 outstanding mathematics and science teachers. Second, we are proposing a Presidential secondary school science and mathematics teaching improvement program which will provide for workshops and training activities, jointly funded with State and local governments and the private sector, and using talents of active research scientists and engineers to strengthen subject matter competence among secondary school teachers of science and mathematics.

Although the work of the National Science Board's Commission on Pre-College Education in Mathematics, Science and Technology will not be completed until late this year, I believe these initiatives are consistent with the report that the Commission will make.

Of course, NSF is coordinating its efforts with those of the Department of Education because the NSF programs complement an initiative in the fiscal year 1984 budget of the department to increase the numbers of qualified secondary school science and mathematics teachers.

In conclusion, let me say that the intellectual state of science in this country is good. U.S. science is the envy of the world. During the past 3½ decades, the United States has had more Nobel Prize winners in science than any other country. And in mathematics the skill of U.S. researchers was again affirmed by the award of two of the last three field medals to American mathematicians.

Today the United States has more scientists and engineers engaged in research and development than any other nation in the Western World. We are winning medals and Nobel Prizes now. But what of the future? Where will the United States be in science 20 years from now?

We are being challenged by the economy in a time of great technological transition.

We are being challenged by the weakened position of the United States in world markets.

We are being challenged by a need to maintain national security.

These challenges require a greater effort in scientific research, a major improvement in the instruments used in university laboratories, an increase of scientific personnel in certain fields, and special efforts to improve the teaching of science and mathematics in secondary schools.

The NSF budget for fiscal year 1984 will help to address these challenges.

Over the three decades of the Foundation's existence, NSF's budgets have had strong bipartisan and public support. I believe we have here a strong, well-conceived budget proposal that once again is worthy of your approval.

For my part, I will work with the National Science Board, with Foundation staff, and with the research community to see to it that support of excellence through competition continues to be the goal in all the Foundation's programs. As I said at the beginning, I couldn't be more pleased with this budget request, and I look forward to the opportunities I will have during the next few months to discuss it with you further.

[The attachments follow:]

SUMMARY OF OBLIGATIONS BY APPROPRIATION
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	CHANGE FY 84/83 AMOUNT	CHANGE FY 84/83 PERCENT
RESEARCH AND RELATED ACTIVITIES APPROPRIATION	$1,064.1	$1,250.7	$186.6	17.5%
SCIENCE AND ENGINEERING EDUCATION APPROPRIATION	30.0	39.0	9.0	30.0%
SPECIAL FOREIGN CURRENCY APPROPRIATION	3.1	2.6	-.5	-16.6%
TOTAL, NSF	$1,097.2	$1,292.3	$195.1	17.8%

O/D 83-506
1-29-83

NSF OBLIGATIONS BY BUDGET ACTIVITY
FY 1983-1984
(DOLLARS IN MILLIONS)

BUDGET ACTIVITY	FY 1983	FY 1984	% CHANGE FY 84/83
MATHEMATICAL AND PHYSICAL SCIENCES	$299.7	$364.3	21.5%
ENGINEERING	100.8	123.0	22.0%
BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES	190.2	223.6	17.5%
ASTRONOMICAL, ATMOSPHERIC, EARTH, AND OCEAN SCIENCES	276.2	334.9	21.3%
U.S. ANTARCTIC PROGRAM	83.2	102.1	22.7%
SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS	44.2	36.8	-16.7%
PROGRAM DEVELOPMENT AND MANAGEMENT	65.3	66.0	1.1%
UNDISTRIBUTED	4.5	.0	-100.0%
SUBTOTAL, RESEARCH & RELATED ACTIVITIES	1,064.1	1,250.7	17.5%
SCIENCE AND ENGINEERING EDUCATION	30.0	39.0	30.0%
SPECIAL FOREIGN CURRENCY	3.1	2.6	-16.6%
TOTAL	$1,097.2	$1,292.3	17.8%

O/D 83-508
1-29-83

MATHEMATICAL AND PHYSICAL SCIENCES
FY 1983–1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
MATHEMATICAL SCIENCES	$34.7	$42.2	21.5%
COMPUTER RESEARCH	29.1	34.7	19.1%
PHYSICS	88.9	107.7	21.1%
CHEMISTRY	66.2	80.2	21.2%
MATERIALS RESEARCH	80.8	99.6	23.2%
TOTAL	$299.7	$364.3	21.5%

O/D 83-510
1-28-83

ENGINEERING
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
ELECTRICAL, COMPUTER, AND SYSTEMS ENGINEERING	$29.3	$36.7	25.3%
CHEMICAL AND PROCESS ENGINEERING	22.3	27.1	21.5%
CIVIL AND ENVIRONMENTAL ENGINEERING	30.0	34.4	14.7%
MECHANICAL ENGINEERING AND APPLIED MECHANICS	19.2	24.8	29.2%
TOTAL	$100.8	$123.0	22.0%

O/D 83-511
1-29-83

BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
PHYSIOLOGY, CELLULAR AND MOLECULAR BIOLOGY	$85.5	$102.7	20.1%
BIOTIC SYSTEMS AND RESOURCES	45.7	53.6	17.1%
BEHAVIORAL AND NEURAL SCIENCES	33.8	37.9	12.2%
SOCIAL AND ECONOMIC SCIENCE	19.8	23.3	17.7%
INFORMATION SCIENCE AND TECHNOLOGY	5.4	6.1	13.0%
TOTAL	$190.2	$223.6	17.5%

O/D 83-612
1-29-83

ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
ASTRONOMICAL SCIENCES	$63.0	$79.3	25.9%
ATMOSPHERIC SCIENCES	75.1	90.6	20.7%
EARTH SCIENCES	34.1	42.1	23.5%
OCEAN SCIENCES OCEAN DRILLING PROGRAM	97.7	115.4	18.1%
ARCTIC RESEARCH PROGRAM	6.3	7.5	19.0%
TOTAL	$276.2	$334.9	21.3%

O/D 83 513
1 29 83

CRUSTAL RESEARCH
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
EARTH SCIENCES			
CORE PROGRAM	$21.1	$24.8	17.5%
MAJOR PROJECTS (E.G., COCORP)	4.0	6.3	57.5%
SUBMARINE GEOLOGY AND GEOPHYSICS	8.9	10.4	15.9%
OCEAN DRILLING	16.5	26.3	59.4%
TOTAL	$50.5	$67.8	34.3%

O/D 83-524
1-31-83

U.S. ANTARCTIC PROGRAM
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
U.S. ANTARCTIC RESEARCH PROGRAM	$9.0	$10.0	11.1%
OPERATIONS SUPPORT PROGRAM	74.2	92.1	24.1%
TOTAL	$83.2	$102.1	22.7%

O/D 83-514
1-28-83

SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984			% CHANGE FY 84/83
		STIA ACTIVITY	WITHIN RESEARCH ACTIVITIES	TOTAL PROGRAM	
INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES	$ 9.9	$ 5.0	$ 7.9	$12.9	30.3%
RESEARCH INITIATION AND IMPROVEMENT	12.2	6.5	14.2	20.7	69.7%
INDUSTRIAL SCIENCE AND TECHNOLOGICAL INNOVATION	14.5	16.5	.0	16.5	13.8%
POLICY RESEARCH AND ANALYSIS	4.1	4.6	.0	4.6	12.2%
SCIENCE RESOURCES STUDIES	3.5	4.2	.0	4.2	20.0%
TOTAL	$44.2	$36.8	$22.1	$58.9	33.3%

O/D 83 515
1 29 83

Mr. **Fuqua** Thank you very much, Dr. Knapp. We appreciate your statement.

I think, as I said in my opening remarks, there has been a lot of constructive improvements in the NSF budget for this year. I do have one statement and maybe a question. This is not aimed at you, Dr. Knapp, let me make this clear. I think you are coming into the program at a very crucial time. The Organic Act of NSF charges NSF with the responsibility of all levels of science education. I am paraphrasing, taking the words out of context. We started work about 2 or 3 years ago addressing the issue of science education as a national concern. After much effort, yesterday afternoon we passed H.R. 1310 out of the committee, trying to correct a problem that was created by NSF because NSF neglected its responsibilities in the area of science and education.

I hope, while we have patched the problems at NSF, you find the problems and correct them yourselves. You have the direct ties to the community through your research grants, with the various disciplines involved as well as in science education. I hope that we won't have to come back again and single out one particular area and address it in a separate bill.

As I say, I am not putting this blame on you. It was there before you got there. I hope all the powers that be in the NSF and the Science Board and the others recognize that National Science Foundation it is a very fine agency, and I support it 100 percent, and even more.

I think we have found where the Foundation has been in this particular area, and it was a decision made over a number of years that left us in the serious situation we find ourselves in.

One of the questions I have is, in your opinion how can science education best be handled? Through those who are participating in the various programs, or should an education directorate be reestablished in NSF?

Dr. **Knapp**. I have looked carefully during the past 3 months at science and engineering education and its history in the Foundation and in the country. It is interesting to note that the decline in the NSF science education budgets started about 1970 and was more or less continuous.

In fact, this downward trend continued until the science education budget reached its lowest level as a percentage of the total NSF budget a year or so ago. I don't understand completely what caused the people of the country and the Congress and the people in the several administrations to decide about 1970 that the science education effort of the Foundation was not so critical as some other areas.

We are looking carefully now at how NSF can best be effective in reversing that downward trend. The Foundation should be restored to a critical role—and I know it can play a critical role—in the right position with the right programs for the 1980's.

Now let me discuss an education directorate for the Foundation, I have looked at the letters exchanged by this committee and Dr. Slaughter, my predecessor. I would like to discuss, among my staff and with others in the administration, what management structure for the Foundation would give the best visibility and effectiveness to the science and engineering education activities; they are now spread within the research directorates and in other parts of the Foundation. If NSF, in fact, does have a much larger role to play in science and engineering education than what it has right now, I would imagine that we would make management changes to take that role into account.

Mr. **Fuqua**. But is there not a responsibility on the part of, say, physicists or chemists or mathematicians to foster education?

Dr. **Knapp**. Absolutely. There is not only a responsibility, but also a desire. I have been heartened by my discussions with the NSF advisory committees. In particular I remember the mathematics advisory committee. It was here a few months ago and I asked: How can working research mathematicians both in universities and outside universities, address best this problem in the secondary and elementary schools?

I found many of them were already doing so as volunteers A man from the University of Washington, for example, was donating a great deal of his time to helping the Seattle school system upgrade its mathematics courses.

The program which we have proposed for the fiscal year 1983 budget is innovative in the sense that it allows the evaluation of, different approaches to this problem. Faculty at universities would assist working schoolteachers at summer institutes and in similar efforts where I think NSF has the most leverage.

Mr. **Fuqua**. I agree with you. I think it is appropriate for this committee to let it be known that we support that and strongly recommend that the various disciplines do their part in trying to correct this serious problem.

I would like to suggest to Congressman Walgren, the chairman of the subcommittee, when we review the budgets of these various areas—particularly this year, but more specifically next year—to see what kind of stewardship they have been doing in those areas.

I think it is highly important that the research areas assume the responsibility that they should in trying to work and help in education as part of their research activities as well.

Dr. **Knapp**. I also have proposed some management changes at the Foundation that will give direct responsibility to the program managers of each directorate for considering features other than the quality of research. One of these features is the health of the educational enterprise for graduate education in those disciplines. I imagine it will help with NSF's activities for pre-college education.

Mr. **Fuqua**. I think it is a very important item and we should look at that in the overall review of their programs. I hope Congressman Walgren and the subcommittee will review that very carefully in the course of the authorization hearings and particularly now that notice is being served that we expect that.

I gather that this meets with your concurrence also?

Dr. **Knapp**. Absolutely.

Mr. **Fuqua**. Maybe the word will get out that we are expecting to review that.

I noticed in the budget request you mentioned that the overall overhead cost in the agency was less than 6 percent.

In the chart that you have accompanying your budgets, or your statement, you have Program Development and Management requesting $66 million for that.

That is that figure, is it not?

Dr. KNAPP. That is that figure.

Mr. FUQUA. It only went up from $65.3 to $66 million, an increase of 1.1 percent?

Dr. KNAPP. Yes.

Mr. FUQUA. I also notice other than the separate line item on science and engineering education, that the next largest increase is in the U.S. Antarctic program. That goes up 22.7 percent.

As you are aware, some of us had the opportunity to visit that program. It was one of the most exciting experiences I think I have ever had in my life. We had a very great time. I realize the large amount of logistics support that is required. Is most of this increase associated with logistics, or will there be more research opportunities available?

Dr. KNAPP. There is a little more opportunity for research but most of the increase is for logistics support. In particular, a maintenance building burned and will be replaced. Some aircraft have—you had an experience with one of the aircraft.

Mr. FUQUA. Yes. We experienced that.

Dr. KNAPP. A long-term maintenance on those ski-equipped aircraft is included in that increase.

Mr. FUQUA. I notice in the statement you made that the President has indicated that this would be supported out of the NSF budget and would not impact the other research activities of the budget. So is it correct to say that there is no effort to secure any funds out of the Department of Defense for the maintenance and support logistics of the military aircraft?

Dr. KNAPP. That is correct. There has been none.

Mr. FUQUA. Mr. MacKay.

Mr. MACKAY. Mr. Chairman, I am sorry I missed a portion of the testimony. I may ask a question you have covered.

I am concerned at the distinction that is made between basic research and applied research. The testimony of Dr. Wilson earlier today seemed to indicate that in the area of super computers, what he perceived as basic research was being construed by the Federal Government—which in this case, I think, would be your agency—as applied research. His point was that part of the limitation is that there aren't any people available to industry who understand the capacities of these computers because the training programs are not being operated in the universities because the computers are not there. He seemed to be saying that this would be a very appropriate major area for Federal funding.

I would appreciate your comments. You may have already covered this, or I may have misconstrued what Dr. Wilson was saying.

Dr. KNAPP. I didn't cover it, and I do want to comment. I agree with Ken Wilson that super computers are critical and that access to super computers by university research centers is important.

The problem of access to large computational facilities by basic scientists is under study right now. I hope that NSF and other agencies of the Government can work together, particularly the Departments of Energy, Defense and perhaps NASA, to develop a coherent program within the country for providing access to super computers by university researchers, no matter who may be funding their research.

The development of super computers, is a much more complex question; Mr. Wilson has a detailed plan of how he would like to see that undertaken. I think that over time we will come to some Government program. However, we must realize that all of the super computers up to this time have been developed by industry without substantial Government direct support, although Government is usually the customer for the first, or first five or six, of any new computers. Keeping that relationship with the industry is important.

Mr. MacKay. Thank you.

Mr. Walgren [presiding]. Mr. Bateman, the Chair would be happy to recognize you.

Mr. Bateman. I would be happy to ask a question, Mr. Chairman

Dr. Knapp, as you, I imagine, are aware, the Barnes Subcommittee of the Nuclear Science Advisory Committee has recommended the construction and operation of a four GEV CW electron accelerator which means a great deal more to you than it does to me, I am sure.

To the extent of your familiarity with that recommendation, has the National Science Foundation taken a position or does it have a position as to whether or not the recommendation should be accepted and implemented?

Dr. Knapp. I, personally, and the National Science Foundation, too, have followed the development of the high intensity electron accelerator.

I support the technical reasons for this country having a machine of this kind. Several different centers are competing, as you know. Last week there was a series of meetings here in Washington to judge among various proposals for the site at which this machine will be placed.

The National Science Foundation will not be involved in the funding of this accelerator. It will be funded by the Department of Energy. However, NSF will be involved with the science done on this machine, as supporters of university, faculty, and students who would use it for research. In that sense NSF supports the program fully, whoever wins the competition.

Mr. Bateman. May I follow up with this question: To what extent, if any, has the National Science Foundation become involved in the evaluation of the applications among the various competing entities or organizations?

Do you recommend to the Department of Energy?

Dr. Knapp. No. NSF is not involved except perhaps through some scientists who are funded in their research by NSF programs. Excuse me; that is not quite correct. The evaluating committee is a joint DOE/NSF advisory committee called NSAC. NSF personnel are involved in that joint committee.

Mr. Bateman. So there is an opportunity for the scientific discipline and expertise of the Science Foundation to enter into the selection that will be ultimately officially made by the Department of Energy?

Dr. Knapp. That is correct.

Mr. Bateman. I would take it then that you are somewhat sanguine that the kind of policy statements you have indicated on behalf of enhancement of the research capabilities of colleges and universities will be attended to and focused upon in that selection process?

Dr. KNAPP. Yes. The most important feature for the scientific researchers supported by NSF, is that this facility be open and available to all scientists who would wish to use it and that it be built and run in a cost effective way. At this point, the National Science Foundation wouldn't judge whether a national laboratory or university would be the best site for the device so long as access by university faculty was open wherever the device was located.

Mr. BATEMAN. If my time permits, Mr. Chairman, my recollection in looking over your statement is that it made some reference to the necessity for upgrading university-based research instrumentation and capabilities even to the lesser emphasis—if I may express it that way—of national laboratories.

I am not sure what I just heard is as consistent with what I read in the statement as I would like for it to have been.

Dr. KNAPP. Let me comment on my view of how large scientific facilities should be operated.

In the particular case you are discussing, it may not be completely applicable, but it is clear that large instruments such as the Very Long Baseline Array, or the Fermi Lab accelerator in Chicago are so large that they would dominate and be counterproductive on a university campus. They are as big as the campus itself for all disciplines. So it has served the country well to put very large facilities at national laboratories built for that purpose, like the Fermi Lab.

The electron machine is intermediate in size. I imagine the choice of a university campus or a national laboratory would be made on the basis of the scientific quality of the proposal, with some bias toward the university, if the device is still small enough. It can be a good part of the training of graduate students at a university.

Mr. BATEMAN. I might add parenthetically that to the extent there are concerns as to the availability of space as to one of the applicants I am familiar with, you need not be concerned.

The space is available and happily will be made available.

Thank you, Doctor.

Mr. WALGREN. Thank you, Mr. Bateman.

Mr. McGrath.

Mr. MCGRATH. Thank you, Mr. Chairman.

Welcome, Dr. Knapp. I understand we are going to have a little meeting this afternoon.

I have a series of questions regarding something that was recently brought to my attention, and that is in the fiscal year 1984 budget submission by the EPA, that 50 percent of the moneys requested for exploratory research programs will be managed by NSF for contracting out long-term research.

This committee has been aware and is aware of the success of the NSF peer review system and has very much criticized in the past—and will, I am sure, in the immediate future—the EPA for its inability to secure high quality, long-term research.

However, some of us are concerned about the fast track that this proposal seems to be on, and I am just wondering whether or not you are aware of such agreements between the EPA and the NSF and for how long these talks have been going on?

Dr. **Knapp**. We are talking with the EPA; the track is so fast, we can't keep track of it. I am informed by my staff that only yesterday afternoon, NSF was told that the EPA transfer had been put on hold, whatever that means.

We have had staff negotiations with the EPA. We are working on an interagency agreement, and a draft of the agreement has been prepared. NSF is on track to implement the transfer if EPA and the OMB decide it is the proper thing to do.

NSF has been involved in little but the negotiation on the interagency agreement. We have no policy position.

Mr. **McGrath**. Do you believe that the role of the NSF in this particular endeavor would improve the scientific adequacy of the results of some of the testing that has been going on or will go on?

Dr. **Knapp**. I don't have an opinion. I believe NSF would manage the basic research programs on EPA-like problems if NSF were asked to do so.

Mr. **McGrath**. This proposal is for 40 percent of the budget for the exploratory research programs. If this became a reality with 40 percent, would you be willing to proceed with 100 percent?

Dr. **Knapp**. The understanding is that the 40 percent represents new grants to be made in fiscal year 1984, and that the entire program would be under NSF's purview in later years.

Mr. **McGrath**. I thank you.

Mr. **Walgren**. Thank you, Mr. McGrath.

I wanted to just ask at the outset, as I understand the budget you are submitting, there will be actually a net increase with respect to handicapped engineering.

This would be a change in direction from the fiscal year 1983 proposals, and I wanted to say that that is not missed by the committee and very much appreciated by some of the members anyway. I would like to encourage you in that context.

Can you just indicate what drew that degree of support from the Foundation?

Dr. **Knapp**. The Engineering Directorate, feels that this is a more important direction for research. It was the internal decision of the Engineering Directorate to increase the support of engineering research for the handicapped.

Mr. **Walgren**. If there's anything specific you could indicate, maybe a little note in the record at this point would be helpful. Perhaps you could—if you have anything further you would like to add, we would be appreciative to hear it.

Dr. **Sanderson**. That program, if you remember, was caught in the budget rescission the Foundation faced in 1982. Since it occurred late in the fiscal year, we were forced to take much of the cut wherever we had uncommitted funds.

As a result, the program was cut back at that time. At the time we said we did not intend to discontinue our support of handicapped research but would provide the support through other parts of the Directorate. In part, at the urging of the Congress and in part on our own reevaluation of the activity, we decided it would be advantageous to continue it as a separately identified program.

Mr. **Walgren**. For the record, that was Dr. Jack Sanderson elaborating at that point.

That brings me to one of the problems going back over several years. In my personal view there were some strong discontinuities in funding within the National Science Foundation starting with the 1981 budget, the 1982 budget, and one of the areas in which funding was not maintained, was the behavioral and social sciences.

You are adding some strength back. You are proposing to add some strength back to the social sciences and to the behavioral sciences, although it is a little unclear from the materials at this point just exactly how much would go to social sciences.

My question is, how do you determine your priorities? You indicate that you consult widely in those determinations. We are not yet back to previous levels of funding in those areas. We had hoped in this committee that we would get at least back to 1981 levels of funding with some dispatch because Dr. Keyworth, in his initial presentations, indicated that he did not believe that the emphasis in those areas should be decreased, and I think the case is well made that from an economic, national interest standpoint there is much to be contributed in the area of productivity in terms of human factors and the kinds of goals that can be pursued through the social sciences.

I would like to ask you how you can proceed in that area and what strengths you would like to see added back in that area?

Dr. **Knapp**. I came into the budget discussions at a relatively late point. However, in this budget the social sciences shared in the increases for the entire Foundation—not to the level at which they had been funded in 1981, it is true—but they did receive a substantial increase.

Mr. **Walgren**. Would that be true as to social sciences as an isolated——

Dr. **Knapp**. In particular, we paid a great deal of attention to the data base support in social sciences and the maintenance of these data bases. They are among the basic tools that social scientists need in order to do research. However, in the social sciences there is no large instrumentation problem, since most of the work doesn't require the kinds of laboratory instrumentation required in the physical sciences.

If you were to look at the support for the personal aspects of the social sciences, you would find the social sciences have not received a much less substantial increase than have the physical sciences. I think Dr. Clark would agree those statements are correct.

Dr. **Clark**. Yes.

Mr. **Walgren**. For the record, this is Dr. Eloise Clark. If you would speak out so the reporter and others in the room can hear, we would appreciate it.

Dr. **Clark**. All right.

Mr. **Walgren**. You are confirming the social sciences as an isolated group as opposed to being joined with——

Dr. **Clark**. Perhaps I could explain.

Our effort in this area is housed under two organizational divisions. One is called social and economic sciences and includes a substantial effort.

The behavioral sciences, which are sometimes included within the social science category, are in the behavorial and neural sciences. Those programs were also increased within that division, although not to the same degree.

We can give you the numbers for the combined level for the record.

[The material follows:]

Behavioral, Social, and Economic Sciences

(Dollars in millions)

	FY 80	FY 81	FY 82	FY 83	FY 84	% 83/84	% 80/84
A. Behavioral Sciences							
- Psychobiology	4.5	4.3	3.6	3.7	3.8	+2.7%	-15.6%
- Cognitive Science	10.0	8.3	5.9	6.6	7.2	+9.1	-28.0
- Anthropology	6.6	6.0	5.5	5.8	6.3	+8.6	- 4.5
	21.1	18.6	15.0	16.1	17.3	+7.5%	-18.0%
Total BNS	(36.8)	(35.2)	(31.7)	(33.8)	(37.9)	(12.1%)	(+3.0%)
B. Social Sciences							
- Economics & Geog.	13.8	10.6	7.0	7.9	10.1	+27.8%	-26.8%
- Social Measurement & Analysis	10.4	8.0	6.0	6.8	7.5	+10.3	-27.9
- Political & Policy Sciences	7.2	6.5	4.5	5.1	5.7	+11.8	-20.8
	31.4	25.1	17.6*	19.8	23.3	+17.7%	-26.0%
Total Behavioral and Social Sciences	52.5	43.7	32.6	35.9	40.6	+13.1%	-23.0%

* - Totals may not add due to rounding.

Mr. **Walgren**. I would just like to underscore the interest of some members in that particular subject. It is something that we can pursue in the authorization hearings.

On another aspect, you indicated that there is support for large scale cooperative research on an international basis, and that it is suggested that since some research may be so large scale, we should be looking for international cooperative agreements in those areas. In the last budget we stepped back from the IIASA Institute in particular. I don't know whether that meant anything for any other international efforts we might carry on. Do you see a growing role for cooperative research on an international basis?

Dr. **Knapp**. My personal view is that science is an international enterprise, particularly basic science; it is a completely international enterprise.

There is a real problem in international science with the exchange of young researchers between universities in developing or developed nations and the United States. The amount of exchange of personnel is much lower than it was a few years ago; I don't understand why. We have suggested that the National Academy of Sciences look at this problem in 1983-84.

NSF funds international science in two ways at this time: one, through international agreements managed by the STIA directorate and two, perhaps a larger amount, through the research directorates, which don't have international responsibilities, per se. I would like to see these two modes of funding international science become more coordinated in the Foundation.

Mr. **Walgren**. I think that the committee should be particularly interested in the management structures and the changes in management that you might bring about. I say that because, with respect to the international scientific activities, there is a decrease in the STIA activity in international cooperative scientific activities; yet there is an increase in the effort that you indicate would be attributable to that area within the research activities themselves.

The difficulty that presents is, it is very difficult for us to track and to understand and, therefore, feel comfortable that the agency is being accountable. There is this tension between wanting to have a separate program which may be more clearly identifiable——

Dr. **Knapp**. It is my duty as Director of the Foundation to develop a management plan and an accounting method that you are completely comfortable with. It should allow you to track what we do in these areas.

I think it is detrimental to science to have international science in a given field separately administered from other support that NSF administers in the same field. It is important that the same program manager, say, for chemistry of a certain kind, be aware of what is going on in the international programs and what is going on within the United States. That is more important to the conduct of good science than the accountability issue. I am certain that we can be accountable if we put our minds to it.

Mr. **Walgren**. It is my understanding the present budget does not show that kind of breakdown?

Dr. **Knapp**. Yes, that is correct. I have a committee of the NSF Assistant Directors drafting a management plan for me. It will allow this budget information to be tracked.

Mr. **Walgren**. I think you would agree that there is sometimes a conflict in purpose between the programs, and although maybe we can do a great deal within the general research activities, there will also be times when the purpose of the program would benefit from separate treatment.

Dr. **Knapp**. Absolutely. Of course, the funding in the STIA directorate is to insure that the other purposes of those activities are fulfilled.

Mr. **Walgren**. I am sure you will receive a receptive ear when we think of trying to do more through the research activities. There are those who feel that our problem in science education was that we did not involve the basic NSF research functions to the degree that they could have been involved with perhaps specific direction that wasn't given them. And I know that there certainly seems to be great potential in trying to accomplish those goals through the integrated research activities rather than having a separate agency for science education alone.

But, again, there is a tendency toward wanting to have the separate function so that it is clearly accountable, because of the fear that we would lose some direct effort if the function is simply merged into the whole.

Dr. **Knapp**. There is no possibility that NSF can fund efforts in precollege science education without a separate organizational function to do it.

The exact form of that organization really must be determined as we see the size of the program, as we see how many aspects are involved, and as we look at NSF internal alinements.

Mr. **Walgren**. You were mentioning earlier you didn't quite know what went into the decision to move away from science education that seemed to be behind this downward trend beginning in 1970. One guess would be that maybe there wasn't a decision, as such, but that as a result of the structure and the guidelines given the research program directors went off into what might have been more interesting areas to them personally, but which weren't pulled back into a function in which science education could clearly make a contribution and which wasn't, perhaps, the most interesting thing for them to do.

Dr. **Knapp**. That is a guess, it is possibly correct. I would also make another guess; after all, it was a function of the administration, the Science Foundation, and the Congress—all three together somehow allowed these budgets to go down slowly from 1970.

Another factor of that budget decrease was the feeling—I think an incorrect feeling—that in the early 1970's the United States had an abundance of scientific personnel. We didn't need to worry about whether we were producing more scientists. After all, Ph. D. scientists were driving taxicabs, and why should we worry? Science education wasn't a crisis situation.

It was a combination of many different factors. I don't think it was internal pressures within the Foundation that can be blamed for the steady decrease of the education budgets from 1968 onward.

Mr. **Walgren**. It is hard to think it was the Congress, because it is my understanding that this committee has increased the education budget over whatever was requested in every year of the last 13 years. I would wonder whether we ought to be looking for what might have been the inadvertent interaction of these forces perhaps more than a conscious decision.

Dr. **Knapp**. I will keep your thought clearly in mind.

Mr. **Walgren**. We would be very interested in trying to think with you about the management structure because I think certainly that is a way that you can cause these things to happen.

I know congressionally there is concern that one of the ways you get rid of a program is to put it in a larger pool and then it gradually gets lost. We are concerned about things like the experimental program to stimulate competitive research which was a very direct interest of many members on the committee and which did do something good in terms of geographic distribution.

Dr. **Knapp**. I am told it is a quite successful program.

Mr. **Walgren**. It is also my understanding now that will be at least folded into a larger structure in which it might get lost.

Dr. **Knapp**. It is my duty as the Director of the NSF to make sure that it doesn't. I will be glad to discuss with the committee the management structure that we propose.

Mr. **Walgren**. Please know that we are very interested in tracking those programs and somehow or other the budget materials that we do get should enable us to do that.

We will look forward to the authorization hearings and perhaps be able to ask some more specific questions about the management structure.

Mr. Gregg.

Mr. **Gregg**. Thank you, Mr. Chairman. It is a pleasure to have you here, Doctor. I am sorry I wasn't here for your entire testimony. Unfortunately, the postal workers caught up with me as I was headed down the hall.

Since I want to get my leaflets delivered, I felt I should talk with them.

I am impressed with you. In the 3 months you have been at NSF, I have been following your activities, although from a distance. I have been impressed with what you have been doing so far. I am looking forard to working with you, quite honestly.

You will find that I have an unconscionable bias for elementary and secondary school education, as some of your staff may have told you from our hearings we went through the last few days on the emergency bill.

I recognize that this is a minor role within the NSF, but it is one in which I have an interest. I am also fascinated by what the NSF is doing in the basic science areas, in the ocean drilling and Antarctic areas.

I just have a couple of questions about the bill we took up yesterday. One of the proposals we made was that OSTP be a coordinator between DOE and NSF. I wondered if you felt that would be practical in the area of the workshops and other areas where this bill has overlap?

Dr. **Knapp**. I don't have an opinion about whether it would be practical. It is quite possible, however, to coordinate the role of the NSF and the role of the Department of Education. I see no problem between the two agencies with respect to their proper roles in the procollege education program.

Mr. **Gregg**. You have had a chance, I presume, to see this bill 1310?

Dr. **Knapp**. Only briefly. I saw it this morning when I came in. I understand some of the events occurred late yesterday afternoon. I have not had a chance to restudy it.

Mr. **Gregg**. Then I will pass on asking questions in that area.

I am sure you went over this in some detail, but do you feel your budget, $1.3 billion that you are proposing, is adequate to address all the various areas that the NSF is required to address this year?

Dr. **Knapp**. Yes, it is.

Mr. **Gregg**. The moneys that are going to be spent—there is $50 million being added in, as I recall, for Presidential incentive grants. Is that what the term is?

Dr. **Knapp**. No, the $50 million is for the Department of Education.

Mr. **Gregg**. It is $20 million you are getting?

Dr. **Knapp**. $20 million.

Mr. **Gregg**. Last year we gave you $15 million for the teacher incentive program and for what would basically be expanded workshops or education of teachers?

Dr. **Knapp**. Yes, that is correct.

Mr. **Gregg**. Do you think—and the chairman was talking about this—do you think those functions are going to—and you mentioned that you are going to require a separate, more defined area within the agency?

Dr. **Knapp**. NSF must look carefully at the way it manages this. And NSF also must look at the final decision by the Congress on the size of the programs before it can decide exactly how to manage the programs.

Preliminary plans on changing NSF management at this point have not been made.

Mr. **Gregg**. How do you feel about this whole movement within the country, the Congress?

I realize we move in fads as a nation. How do you feel about this emphasis on science and math education, and the role NSF should play in it? Do you think NSF should get in the elementary and secondary schools?

Dr. **Knapp**. Yes, NSF has a role to play. The country needs a coherent national approach to its educational problems. It is not just science and mathematics education; we really have educational problems outside science and mathematics. To develop a good approach is an important priority of this Congress, I think. I am sure you will be debating it at great length.

Mr. **Gregg**. I notice the Senate sent you a letter that raised the issue of the lack of specificity between the NSF and DOE to the proposal that you made—maybe you didn't make it—but that went before the Senate Appropriations Subcommittee relative to math/science training. Have you resolved that issue with the Senate?

Dr. **Knapp**. No; we haven't. We will take that up with the Senate this week.

Mr. **Gregg**. Do you think you can resolve it?

Dr. **Knapp**. We certainly can resolve it. We were quite pleased with the broad nature of the mandate that we had and the experimental nature of the program that we proposed. We will work with the Senate to develop a program suitable for the money available and relevant to their worries and their concerns.

Mr. **Gregg**. I guess the main concern was separating the responsibility between the NSF—and Department of Education.

Dr. **Knapp**. I don't think there is a problem of separating responsibilities in the NSF proposals and the Department of Education proposal.

The program that NSF proposed used, as Chairman Walgren said, the expertise of the scientists such as those working in programs, funded by NSF. We want to use them to train teachers in summer institutes and similar efforts. It wasn't specified that it had to be a particular kind of summer institute, or even in the summer, or even an institute.

It could be proposals from universities or school boards or education associations to carry out teacher training programs—not for new teachers—but teachers already in the system whose teaching, and knowledge needed to be upgraded.

We proposed the use of scientists and engineers such as those already working as Foundation grantees to make these programs more effective. The Department of Education's program was quite different. It proposed grants to the States for supporting students who were training to become teachers.

Mr. **Gregg**. I like what you describe as your role. However, I think the Senate committee was trying to prescribe your activities more severely than that and keep you out of areas of workshops and activities within education of the teachers, whether they were new teachers or old teachers.

I happen to feel NSF has a unique capacity to address that area and even more so than Department of Education, in some sense, in that it has more credibility with the teaching faculties.

I hope you will assert what I think is legitimate claim in that area.

Thank you very much.

Mr. **Walgren**. Thank you, Mr. Gregg.

We certainly appreciate your coming, Dr. Knapp. We look forward to our future hearings on these subjects.

Thank you, and we will see you on Friday.

[Whereupon, at 1 p.m., the committee was adjourned.]

1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

FRIDAY, FEBRUARY 25, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:40 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Brown, Mineta, Bateman, and Skeen.

Mr. Walgren. Let me call the subcommittee to order so we can proceed.

Today marks the first of four subcommittee hearings on the authorization of the National Science Foundation budget for fiscal year 1984. As in the past few years, we will try to focus each of these hearings on subject areas rather than necessarily on line items in the budget as proposed.

In today's hearing, we will look at the administration's proposal for the education activities of the Foundation.

Let me say at the outset that in general we certainly respond favorably to seeing the Foundation come forward with a budget request providing real growth in almost all of the major programs of the agency. The budget calls for a total of $1.292 billion, an increase of $195.1 million or 17.8 percent over their current planned budget for fiscal year 1983. The decision to double the funding for research instrumentation, as well as providing renewed thrusts which include mathematics, materials science, engineering, and the Earth sciences, is a clear change from previous years' budgets.

Although not representing as large an increase as in other areas, I particularly want to note with approval the direction the Foundation is going in reversing its position of last year in eliminating the engineering research to aid the handicapped. They have reinstated those programs in fiscal year 1983 with a 15-percent proposed increase for fiscal year 1984. The $2.3 million in this item is not the largest in the NSF budget, but last year's testimony certainly underscored that these moneys are extremely valuable and necessary to helping resolve the problems of the handicapped. Regarding the science and engineering education activities, I wish I could be as positive. Although a 23-percent increase in the overall amounts seems substantial, our past actions have so eroded the base in this activity that the increase is not really significantly over past efforts. A large relative increase in a small amount still leaves you with a small amount. I would also note that in a budget increase of $195 million, the $5 million for precollege education, as an increase, is not a major portion of the total. It is hardly up to the level of a major initiative as claimed by the President in his state of the Union address or as restated in the Foundation's testimony earlier this week. I think the committee will be particularly interested in pursuing this question further.

That said, the committee is pursuing independently a congressional initiative which would provide a new significant base to the Foundation's education activities. That initiative enjoys broad bipartisan support and if straws in the wind are measures, is going to be approved by the Congress. As provided for in Tuesday's markup, NSF would have an additional $130 million, targeted to specific and particularly important areas in precollege, postsecondary, and public education. I know that the committee is extremely interested in pursuing discussions with the Foundation to consider the administration's proposals, particularly in light of these recent congressional initiatives in the education area.

I would finally note that some of our discussion today must focus on the fiscal year 1983 proposed education plan. I understand there remains some concern as to the most effective way to allocate those very limited resources. I look forward to hearing the Director's responses and comments on that plan.

I would like at this point to recognize Mr. Bateman.

Mr. **Bateman**. Thank you, Mr. Chairman.

Having just arrived, I will sort of get with the flow, and perhaps have some questions shortly.

Mr. **Walgren**. Fine.

If the minority has a statement in opening that they would like to make for the record, we would be certainly happy to have that included whenever you would be prepared to submit it.

Mr. **Bateman**. Thank you, Mr. Chairman.

Mr. **Walgren**. The Chair would like to recognize Mr. Brown for any initial comments.

Mr. **Brown**. I would like to recognize the chairman for an excellent statement, and I have nothing further to add.

Mr. **Walgren**. Thank you, Mr. Brown.

We want to start with William Coleman and proceed from there to the Director of the Foundation, who is accompanied by Dr. Branscomb.

Mr. Coleman, we understand, has some time conflicts, and we want to accommodate your schedule. We are really pleased to have you here today. Mr. Coleman is cochair with Cecily Selby of the National Science Board Commission on Precollege Education, Mathematics, Science and Technology. Mr. Coleman comes from my State of Pennsylvania, from the eastern part of the State, Philadelphia. He is a lawyer in the firm of O'Malvaney & Myers, but we know you best as the Secretary of Transportation under former President Ford. We are very pleased that you are giving time to this subject, and we appreciate your coming and presenting your views to the committee this morning.

Mr. Coleman.

STATEMENT OF WILLIAM T. COLEMAN, JR., COCHAIRMAN OF THE NATIONAL SCIENCE BOARD COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

Mr. Coleman. Good morning, Mr. Chairman and members of the subcommittee.

Today I am going to report on the activities of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, of which I have the privilege of being cochairman. I will not otherwise comment on the activities or plans of the National Science Foundation. Dr. Knapp and Dr. Branscomb will cover these items.

As you know, the Commission was established in April 1982 by the National Science Board in response to a well-documented decline in precollege student participation and achievement in mathematics, science, and technology. That decline is occurring at the same time that this society and American jobs are becoming more and more scientifically and technologically oriented.

Other industrial nations spend more time in the classroom on education in mathematics, science, and technology and turn out more mathematicians, scientists, and engineers per capita than we do.

As we said in the Commission's first interim report:

> Improved preparation of all citizens in the fields of mathematics, science and technology is essential to the development and maintenance of our Nation's economic strength, military security, commitment to the democratic ideal of an informed and participating citizenry, and leadership in mathematics, science, and technology.

There is no need for me to elaborate further on this topic. I admire the way you have seized the problems and intend to do something about them. The Commission is moving toward formulating recommendations for solving these complex problems.

In establishing the Commission, the NSB recognized the need for a new and fresh look at the way mathematics and science education is provided at the precollege level in this country.

Clearly the old ways are not working well enough. Moreover, education about technology is virtually nonexistent at the precollege level. To get that fresh look, the NSB convened our group of 20 from virtually all sectors of society.

Our members include representatives of State and local governments, business and industry, precollege and higher education, the professional science and engineering communities, the military, the media, and the law.

Before our deliberations began, some commissioners were, and some were not, experts in precollege education, although all are experts in their respective fields.

This diversity in the backgrounds is one of our unique strengths. Clemenceau once said that war is a much too serious matter to be left to the military. Likewise, the education of our children is too important to leave solely to professional educators.

We hope that our joint perspective will be novel and fresh and will reflect a real grass roots involvement. We expect that our recommendations, which are due out in final form in October of this year, will include new and more productive ways of looking at not-so-new problems.

The National Science Board charged the Commission with producing an explicit plan of action. We are not doing just another study of what is wrong with precollege education. Our charge is to examine the appropriate roles for various groups and individuals and to arrive at a set of principles and strategies to guide efforts at improving precollege education in this country. I assure you we will accomplish our goals and mission.

Recognizing the diversity in commissioners' background and expertise, as well as our unique charge, we organized our activities into three phases. In fact, we completed the first phase, problem definition, at our first meeting in July 1982.

We then published a problem definition statement as our first report titled "Today's Problems, Tomorrow's Crises."

More than 30,000 copies of this report have been circulated to date, including copies to each of the Nation's 16,500 school districts. We published this report because we believe that, although many professional educators may have long been aware of the precollege education problems, most other communities have not shared that knowledge. We believe that a root cause of precollege education problems is a lack of broad public appreciation of the need for mathematics, science, and technology education for all students.

Mark Twain once said that a "classic" is something that everybody wants to have read and nobody wants to read.

Most people know that the Nation needs people who understand mathematics, science, and technology, but many don't appreciate the importance of understanding it themselves. Publishing our first report was one way the Commission could contribute to increasing public awareness, a condition we consider essential if our ultimate recommendations are to be effective.

At that first meeting we agreed on the three goals that America's educational system must achieve with respect to mathematics, science, and technology. They are: To continue to develop and broaden the pool of students who are well prepared and highly motivated for advanced careers in mathematics, science, and engineering, that is, training the elite and the superstars. It is my understanding today, with respect to producing those outstanding scientists who win their share of Nobel prizes, that America still stands first.

Second, to widen the range of high quality education offerings in mathematics, science, and technology at all grade levels, so that more students would be prepared for and thus have greater options to choose among technically-oriented careers and professions. So far I cannot make the same statement that the United States maintains a position of leadership with respect to that second objective.

Third, to increase the general mathematics, science, and technology literacy of all citizens for life, work, and full participation in the society of the future.

As you know in Congress, there are many public issues that a full understanding means the public must understand scientific terms and the problems. In this task, we are not where we should be.

These goals emphasize the complexity of the problems we are trying to address. We are not just seeking to maintain current numbers or increase the numbers of professional scientists and engineers. We also are not just looking at the population eventually planning to enter technical careers.

We believe a broad understanding of mathematics, science, and technology is essential for all citizens in a free, open, democratic society if they are going to function properly in the last two decades of the 20th century. Our attention is focused toward all people who must live, work, and function in the society of the future.

In addition, we realize that mathematics, science, and technology education do not exist in a vacuum. We cannot simply increase our emphasis on those subjects at the expense of other critical areas such as reading, foreign languages or history.

As my cocommissioner, Governor Evans, recently testified, skills in communication, writing, clear and logical thinking, and a sense of proportion from the humanities are necessary to keep up with the knowledge needed in a rapidly changing society. Thus the problem of allocation of educational time is important for there are only so many hours in the day.

In this regard, it is noteworthy that in the United States the typical school year consists of 180 days, as contrasted with 240 days in Japan. The typical school day in the United States is 5 hours long, 5 days per week, compared with 6- or 8-hour days and a 6-day school week in other countries. These differences are just one of the many areas which we are considering in formulating our recommendations.

The second phase of our work was also begun at our first meeting in July. This phase was devoted to examining and analyzing a wide range of model programs that might have special features deserving broader application in other settings.

To carry out these tasks, we have divided ourselves into four task groups, each focusing on the activities and interests of one sector of society. One task group focuses on Federal, State, and local governments. Another looks at the direct educators, such as teachers and school administrators. The third focuses on those indirectly involved in precollege education, such as associations of professional scientists and engineers, institutions of higher education, business, and industry. The fourth group focuses on those who receive or employ the output of the educational system, such as the military and, again, business and industry.

The four task groups each added three to five more members to broaden their expertise. They made many site visits, participated in numerous conferences and workshops, and met with hundreds of groups interested in precollege education.

In addition, the Commission held a public hearing on the topic of access to quality education for all citizens in December at the Fernbank Science Center in Atlanta. These varied activities are summarized in our interim report to the National Science Board issued on January 20, 1983.

In addition to making site visits and meeting with diverse groups, the Commission has begun a process that we believe is critical to the ultimate success of any efforts to improve precollege education.

The Nation needs to know what it is we want students to know or to be able to do in mathematics, science, and technology when they finish secondary school.

We need to know the goals or targets of precollege education in this area. Therefore, we have commissioned workshops and studies directed explicitly toward that question, for mathematics, for science, and for technology.

We, of course, do not expect to provide definitive answers to such a complex question by the end of the Commission's short life. But we shall disseminate widely the results of those workshops and studies, with the hope of stimulating others to answer the important question what exactly it is we are directing our education efforts toward.

I expect that among the Commission's recommendations will be suggestions of how that defining process might proceed and who should provide the necessary leadership.

The Commission has already begun to develop recommendations. We are planning to have a small set of tentative recommendations available for testing in a public forum to be held in Houston, Tex. on March 26. We will continue an interactive process where we continuously test out our evolving recommendations on our eventual audiences.

We shall remain in contact with this committee, so that your thoughts and reactions to our tentative recommendations can be incorporated into our thinking.

In conclusion, I will attempt to give you some flavor of what I expect our report and recommendations might look like. But, first I would like to reiterate just how complex an issue the precollege education problem is.

At one point in our deliberations we created a matrix with aspects of the problem on one axis and the players on the other axis. That problems-by-players matrix had 1,200 cells in it. Given this complexity, and the fact that there are 16,500 school systems in the United States, I doubt that we will find any simple, yet effective, quick fixes.

Second, we will be searching both for solutions to the immediate problem and for mechanisms to prevent recurrence of the problems in the long term. For we all must keep in mind that the sputnik crisis occurred only 25 years ago. That activated many activities on the part of the Federal Government, but yet we are once again back in a crisis era.

At our January meeting we decided that we will begin by looking at four broad topic areas and asking what various groups or sectors might do in each of them.

The four topic areas include: the curriculum, the condition of the teaching profession, public perceptions and student attitudes, and the effective use of modern technologies in education.

We are also examining how we can use nonschool resources to supplement school resources until all the needed skills are present in the schools.

In each case we shall be asking what various groups should be doing, when, and how. As I mentioned before, we shall begin testing our tentative recommendations at a public forum to be held at the end of March in Houston. We hope to be in close contact with our eventual audiences throughout the recommendation development process.

We believe the only way to get read impact for our recommendations is to obtain general agreement in advance from those who will have to carry them out.

In closing, I wish to thank the committee, and I would like to submit for the record copies of the Commission's first report—stating the problem—and the interim report of its activities.

Thank you for your time. I am looking forward to answering any questions you may have.

[The prepared statement of Mr. Coleman follows:]

PREPARED STATEMENT OF WILLIAM T. COLEMAN, JR.

Thank you Mr. Chairman and Members of the Subcommittee. My name is William T. Coleman, Jr. Thanks for this opportunity to report to you on the activities to date of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, of which I serve as Co-Chair. I will not otherwise comment directly on the activities or plans of the National Science Foundation. Dr. Knapp and Dr. Branscomb will cover those items.

Our Commission, as you know, was established in April 1982 by the National Science Board in response to a well documented decline in precollege student participation and achievement in mathematics, science and technology. That decline is occurring at the same time that our society and American jobs are becoming more and more scientifically and technologically oriented.

Other industrial nations spend more time in the classroom on education in mathematics, science and technology and turn out more mathematicians, scientists and engineers (per capita) than we do. As we stated in our Commission's first interim report:

"Improved preparation of all citizens in the fields of mathematics, science, and technology is essential to the development and maintenance of our Nation's economic strength, military security, commitment to the democratic ideal of an informed and participating citizenry, and leadership in mathematics, science and technology."

There is no need for me to elaborate further on the serious consequences which could befall our nation if our expertise in these areas lags behind the rest of the world. Our Commission is moving toward formulating recommendations for solving these complex problems.

In establishing the Commission, the NSB recognized the need for a new and fresh look at the way mathematics and science education is provided at the precollege level in this country. Clearly, the old ways are not working well enough. Moreover, education about technology is virtually nonexistent at the precollege level. To get that fresh look, the NSB convened our group of 20 from virtually all sectors of society. Our members include representatives of state and local governments, business and industry, precollege and higher education, the professional science and engineering communities, the military, the media and the law. Before our deliberations began, some Commissioners were and some were not experts in precollege education, although all are experts in their respective fields. This diversity in the backgrounds of our commissioners is one of our unique strengths. Someone said that war is a much too serious matter to be left to the military. Likewise, the education of our children is too important to leave solely to professional educators. We hope that our joint perspective will be novel and fresh and will reflect a real grass roots involvement. We expect that our recommendations, which are due out in final form in October of this year, will include new and more productive ways of looking at a not-so-new problem.

The National Science Board charged our Commission with producing an explicit plan of action. We are not doing just another study of what is wrong with precollege education. Our charge is to examine the appropriate roles for various groups and individuals, and to arrive at a set of principles and strategies to guide efforts at improving precollege education in this country. We will accomplish our goals and mission.

Recognizing the diversity in Commissioner's background and expertise, as well as our unique charge, we early on organized our activities into three phases. In fact we've completed the first phase—problem definition—at our first meeting in July 1982. We then published a problem definition statement as our first report, titled *Today's Problems, Tomorrow's Crises*. Over 30,000 copies of this report have been circulated to date, including copies to each of the Nation's 16,500 school districts. We published this report because we believe that although many professional educators may have long been aware of the precollege education problem, most other communities have not shared that knowledge. And we believe that a root cause of precollege education problems is a lack of broad public appreciation of the need for math, science and technology education for all students. Mark Twain once said that a "classic" is "something that everybody wants to have read and nobody wants to read." Most people know that our nation needs people who understand mathematics, science and technology, but many don't appreciate the importance of understanding it themselves. Publishing our first report was one way we could contribute to increasing public awareness, a condition we consider essential if our ultimate recommendations are to be effective.

At that first meeting we also agreed on the three goals which America's educational system must achieve with respect to math, science and technology. They are:

To continue to develop and broaden the pool of students who are well prepared and highly motivated for advanced careers in mathematics, science and engineering (i.e., training the elite and the Superstars);

To widen the range of high-quality education offerings in math, science and technology at all grade levels, so that more students would be prepared for and thus have greater options to choose among technically oriented careers and professions; and

To increase the general mathematics, science and technology literacy of all citizens for life, work and full participation in the society of the future.

These goals emphasize the complexity of the problem we are trying to address. We are not just seeking to maintain current numbers or increase the numbers of professional scientists and engineers. we also are not just looking at the population eventually planning to enter technical careers. we believe a broad understanding of mathematics, science and technology is essential for *all* citizens in a free, open, democratic society. Our attention is focused toward all people who must live, work, and function in the society of the future. In addition, we realize that math, science and technology education do not exist in a vacuum. We cannot simply increase our emphasis on those subjects at the expense of other critical areas such as reading, foreign languages or history. As my co-commissioner, Governor Evans said when he testified before another House Subcommittee in September, "skills in communication, writing, clear and logical thinking and a sense of proportion from the humanities are necessary to keep up with the knowledge needed in a rapidly changing society." Thus, the problem of allocation of educational time is important. For there are only so many hours in the day., In this regard, it is noteworthy that in the United States, the typical school year consists of 180 days, as contrasted with 240 days in Japan. The typical school day in the United states is five hours long, five days per week, compared with six- or eight-hour days and a six-day school week in other countries. These differences are just one of the many areas which we are considering in formulating our recommendations.

The second phase of our work was also begun at our first meeting in July. This phase was devoted to examining and analysing a very wide range of model programs that might have special features that would merit broader application in other settings. During the second phase, we also established contact with a wide variety of organizations and individuals with interests and activities related to precollege education. We hoped to learn their views of the problem and of appropriate remedies.

To carry out these tasks we have divided ourselves into four Task Groups, each focusing on the activities and interests of one sector of our society. One Task Group focuses on Federal, State and local governments. Another looks at the direct educators, such as teachers and school administrators. The third focuses on those indirectly involved in precollege education, such as associations of professional scientists and engineers, institutions of higher education, business and industry. The fourth group focuses on those who receive or employ the output of the educational system, such as the military and, again, business and industry.

The four Task Groups each added three to five additional members to broaden their expertise. They made many site visits, participated in numerous conference and work shops, and met with literally hundreds of groups with interests in precollege education. In addition, the Commission held a public hearing on the topic of "access to quality education for all citizens" in December, at the Fernbank Science Center in Atlanta. These varied activities are summarized in our *Interim Report to the National Science Board* issued on January 20, 1983.

In addition to making site visits and meeting with diverse groups, the Commission has begun a process that we believe is critical to the ultimate success of any efforts to improve precollege education. The nation needs to know what it is we want students to know or to be able to do in math, science and technology when they finish secondary school. We need to know the goals or targets of precollege education in this area. Therefore, we have commissioned workshops and studies directed explicity toward that question—for math, for science and for technology. We, of course, do not expect to provide definitive answers to such a complex question by the end of the Commission's short life. But we shall disseminate widely the results of those workshops and studies, with the hope of stimulating others to answer the important question of what exactly it is we are directing our education efforts toward. I expect that among the Commission's recommendations will be suggestions of how that defining process might proceed and who should provide the necessary leadership.

The Commission began its third phase of activity at its most recent meeting in January. This phase is aimed at framing recommendations and the appropriate mechanisms for implementing them. At that meeting we selected broad topic areas toward which our initial efforts will be directed. We are planning to have a small set of tentative recommendations available for testing in a public forum to be held in Houston on March 26. We will continue an interactive process where we continuously test out our evolving recommendations on our eventual audiences. We shall remain in contact with this Committee, so that your thoughts and reactions to our tentative recommendations can be incorporated into our thinking.

I am sorry that I cannot yet share with you any firm recommendations. We are still too early in the development process. But I can give you some flavor of what I expect our report and recommendations might look like.

First, I would like to reiterate just how complex an issue the precollege education problem is. At one point in our deliberations we created a matrix with aspects of the problem on the other axis. That problems-by-players matrix had 1,200 cells in it. Given this complexity, and the fact that there are 16,500 school systems in the United States, I doubt that we will find any simple, yet effective, "quick fixes."

Second, we will be searching both for solutions to the immediate problem and for mechanisms to prevent recurrence of the problems in the long term. For we all must keep in mind that the Sputnik crisis occurred only 25 years ago. Many programs were instituted right after Sputnik, yet here we are again.

At our January meeting we decided that we will begin by looking at four broad topic areas and asking what various groups or sectors might do in each of them. The four topic areas include: the curriculum, the condition of the teaching profession, public perceptions and student attitudes, and the effective use of modern technologies in education. We are also examining how we can use non-school resources to supplement school resources until all the needed skills are present in the schools. In each case, we shall be asking what various groups should be doing, when and how. As I mentioned before, we shall begin testing out tentative recommendations at a public forum to be held at the end of March in Houston. We hope to be in close contact with our eventual audiences throughout the recommendation development process. For we believe the only way to have our recommendations have real impact is for there to be general agreement in advance from those who will have to carry them out.

In closing, I would like to submit for the record copies of the Commission's first report, stating the problem, and its interim report of activities. Thank you for your time. I am looking forward to answering any questions you may have.

Mr. **Walgren**. Thank you very much, Mr. Coleman.

We appreciate that submission and perhaps we will have the staff look at the two reports you have submitted for enclosure of pertinent parts in the record, or perhaps it should best be simply referred to, rather than totally incorporated in the text of the record.

But your Commission's reports will be referred to at this point in the record.

[The Commission's first report, "Today's Problems, Tomorrow's Crises," follows. The interim report is available in the subcommittee's files.]

NATIONAL SCIENCE BOARD
NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

NSB COMMISSION ON PRECOLLEGE
EDUCATION IN MATHEMATICS,
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October 18, 1982

Dr. Lewis M. Branscomb
Chairman
National Science Board
National Science Foundation
Washington, D.C. 20550

Dear Dr. Branscomb:

We are most pleased to transmit to you the first formal report of our Commission, "Today's Problems, Tomorrow's Crises." This report represents the Commission's assessment of the condition of precollege education in mathematics, science and technology in this country.

The problems summarized in our report--if left unresolved--will escalate in the years ahead. Thus, all Americans need to recognize the broad importance of mathematics, science and technology in the education of our youth. We hope, accordingly, that our report will receive wide dissemination.

The seriousness of the current situation underscores the Commission's resolve to develop, during the remainder of its life, an agenda for action for all sectors of society.

Sincerely,

Cecily C. Selby

William T. Coleman, Jr. Cecily Cannan Selby

Today's Problems, Tomorrow's Crises

Introduction

Across the United States, there is escalating awareness that our educational systems are facing inordinate difficulties in trying to meet the needs of the Nation in our changing and increasingly technological society. We appear to be raising a generation of Americans, many of whom lack the understanding and the skills necessary to participate fully in the technological world in which they live and work. Improved preparation of all citizens in the fields of mathematics, science, and technology is essential to the development and maintenance of our Nation's economic strength, military security, commitment to the democratic ideal of an informed and participating citizenry, and leadership in mathematics, science and technology.

To meet these ends, our formal and informal education systems must have the commitment and the capacity to achieve three equally important goals:

- to continue to develop and to broaden the pool of students who are well prepared and highly motivated for advanced careers in mathematics, science and engineering;
- to widen the range of high-quality educational offerings in mathematics, science and technology at all grade levels, so that more students would be prepared for and thus have greater options to choose among technically oriented careers and professions; and
- to increase the general mathematics, science and technology literacy of all citizens for life, work and full participation in the society of the future.

The first goal needs little explanation, since maintenance of U.S. scientific and technological capacity requires superbly educated mathematicians, scientists, and engineers. As the total number of 18-year-olds in the population continues to decrease into the 1990's, the percentage of high school graduates entering preprofessional, college-level courses in science and engineering must increase to meet future manpower needs. In addition, to meet the country's needs for excellence, creativity, and innovation in its scientific work, we must develop and utilize the talents of all Americans, including women and minorities (now currently underrepresented in the science and engineering professions).

The critical value of the second goal has become widely recognized during the past few years. The current gap between opportunities for those with and without credentials in mathematics, science and technology will increase dramatically as the technological complexity of U.S. society increases. Industrial leaders have identified the current shortage of trained technicians as a serious barrier to increased productivity. Military commanders echo this concern about their manpower requirements for meeting national security needs. In such professions as law, journalism, and business management, there is also a growing demand for men and women with backgrounds in mathematics, science, and technology. The current and increasing shortage of citizens adequately prepared by their education to take on the tasks needed for the development of our economy, our culture, and our security is rightly called a crisis by leaders in academe, business, and government.

The third goal is rooted in Thomas Jefferson's familiar dictum that an educated citizenry is the only safe repository of democratic values. The life and work of Jefferson and others make clear that a broad understanding of the relationships between science and society was considered by early Americans as integral to the ideal of the Republic. To lead full lives and to participate with confidence in contemporary American society, citizens need an understanding and appreciation of mathematics, science and technology.

This report reviews the status of math, science and technology instruction in our educational systems and explores some of the key problems and challenges facing those systems. The central conclusion to be drawn is that, in the aggregate, the U.S. educational systems currently are not satisfactorily achieving the second and third goals, and they will need assistance, although perhaps to a somewhat lesser extent, to meet the first.

The Principal Concern: Declining Achievement and Participation at a Time of Increasing National Needs

Data from a number of sources have documented declining student achievement in mathematics and science, as indicated by declines in:

- science achievement scores of U.S. 17-year-olds as measured in three national assessments of science (1969, 1973, and 1977);
- mathematics scores of 17-year-olds as measured in two national assessments of mathematics (1973, 1978); the decline was especially severe in the areas of problem-solving and applications of mathematics;
- mathematical and verbal Scholastic Aptitude Test (SAT) scores of students over an 18-year period through 1980; and
- students prepared for post-secondary study. Remedial mathematics enrollments at four-year institutions of higher education increased 72 percent between 1975 and 1980, while total student enrollments increased by only seven percent. At public

four-year colleges, 25 percent of the mathematics courses are remedial; and at community colleges, 42 percent are.

The proportion and qualifications of high school seniors who will major in mathematics, science, and engineering have remained roughly constant over the past 15 years, although college engineering enrollments have increased steadily since the mid-1970's. Some students are also receiving more advanced experiences in secondary school science and mathematics as indicated by performance on advanced placement tests.

Nonetheless, adequate mathematics and science course opportunities are not available for *all* talented and motivated students. As many as one-third of U.S. secondary schools do not offer sufficient mathematics to qualify their graduates for admission to accredited engineering schools. Only one-third of the 21,000 U.S. high schools teach calculus, and fewer than one-third offer physics courses taught by qualified physics teachers.

The evidence on student participation and achievement indicates a wide and increasing divergence in the amount and quality of the mathematics, science and technology education acquired by those who plan to go on to college and study in those areas and by those who do not. Students in the latter category generally stop their study of mathematics and science at a relatively early age, perform considerably less well on achievement measures than the career-bound, and do not have opportunities to pursue appropriate courses in contemporary technology. Only nine percent of the students graduating from vocationally oriented secondary school programs in 1980 took three years of science, and only 18 percent took three or more years of mathematics. Hence, it is clear that while the first goal stated in the introduction presently is being fulfilled reasonably well, the second and third goals are not. In fact, the educational system may actually have carried out these latter goals better 20 years ago: the proportion of public high school students (grades 9 to 12) enrolled in science courses has declined since that time. Thus, the principal concern with student participation and achievement is with those who do not plan careers in mathematics, science, or engineering.

In addition, wide differences persist in achievement and participation levels among students from different social groups. Women have traditionally participated less than men in science, and members of various minority groups (specifically, if not exclusively, American Indians, Black Americans, Mexican Americans and Puerto Ricans) have participated less and performed less well on standard science and mathematics achievement tests than their white counterparts. Approximately 20 percentage points separated the mathematics achievement scores of 17-year-old black and white students on national assessment tests in both 1973 and 1978. Approximately 15 percentage points separated 17-year-old Hispanics and whites in both years. Between 1973 and 1978, nine-year-old black students showed a definite improvement in performance on mathematics achievement tests, while the average performance of nine-year-old white students declined and that of Hispanics remained constant.

Specific Contributory Problems

Studies and analyses of conditions in the U.S. educational system—including both its formal and its informal components—point to four problems that contribute to declining student participation and achievement levels.

Teachers

Individual teachers have considerable discretion in the selection of course content and instructional approaches and, therefore, play a pivotal role in the education of students. Superior teachers of mathematics, science and technology can motivate students to do well in their courses and can stimulate students to take more advanced courses and consider technically or scientifically oriented careers. Mediocre and poor teachers may dampen the enthusiam of good students and fail to recognize and stimulate the development of potential talents in others. Therefore, the documented shortage of superior teachers must be considered a prime contributing cause of decreasing student participation and achievement in mathematics, science and technology.

There is also a growing shortage of qualified secondary school mathematics and physical science teachers. In 1981, 43 states (of 45 responding) reported a shortage of mathematics teachers. For physics teachers, 42 states reported such shortages. In the same year, 50 percent of the teachers newly employed nationwide to teach secondary science and mathematics were actually uncertified to teach those subjects. From 1971 to 1980, student teachers in science and mathematics decresed in number—threefold in science and fourfold in mathematics—and only half of them have actually entered the teaching profession. In addition, 25 percent of those currently teaching have stated that they expect to leave the profession in the near future.

Some of the problems that affect the participation and achievement of students at all grade levels are:

- Among certified teachers of high school mathematics and science, very few have had the formal educational preparation required to provide students with an understanding of modern technology.
- There are few available opportunities for certified mathematics and science teachers to update or broaden their skills and backgrounds. Such training opportunities are essential due to the rapid advances taking place in mathematics, science and

technology and the need to introduce new types of upper level courses for nonspecialists.

- There are few inservice programs to certify teachers who are presently not qualified to teach mathematics and science.
- Most teachers in the primary and middle school grades have not had training in science and mathematics or courses in methods to teach these subjects.
- District-level supervision has been reduced as a result of financial retrenchment or has been shifted from instructional to administrative support. As a result, relatively few people are available outside the classroom to provide quality control or to assist teachers with pedagogical problems.

Classrooms

Deficiencies in the numbers and qualifications of mathematics and science teachers are exacerbated by classroom conditions, including inadequate instructional time, equipment, and facilities.

The time available for adequate instruction in U.S. schools is far more limited than in other advanced countries. In the United States, the typical school year consists of 180 days, as contrasted with 240 days in Japan. This is further reduced by absenteeism, which amounts to an average of 20 days per school year. The typical school day is five hours long, compared with six- or eight-hour days in other countries. In addition, many periods of varying length throughout school days and weeks are devoted to nonacademic pursuits, both reducing the hours available for instruction and diverting the time and energy of teachers to noninstructional duties. Problems associated with student discipline and motivation, which are severe in some schools and affect the general learning environment, have been well publicized.

Many science courses in schools throughout the country are being taught without an adequate laboratory component or with no laboratory at all. In some cases, laboratory apparatus is obsolete, badly in need of maintenance, or nonexistent. In other cases, such apparatus is not used because of a lack of paraprofessionals or aids to set up and maintain equipment, a condition that has become increasingly important due to the greater concern for safety in the schools.

Curricula

Curricula in mathematics and in several scientific disciplines were developed with federal support two or more decades ago to provide rigorous, modern course work for high school students interested in careers in mathematics, science and engineering. These curricula, and several generations of privately-developed successors, continue to serve their purpose, though many need to be revised.

Mechanisms must be developed to incorporate effectively into the curricula changes associated with advances in the disciplines and evolving contemporary technologies.

Another curricular concern is that upper level high school courses based on these curricula are too abstract and theoretical for most students. In fact, serious doubts exist about whether many of the commonly offered mathematics, science and technology courses in the secondary schools are, in their present form, of much value to students planning careers outside of mathematics, science or engineering. Few courses or widely accepted curricula are available with the explicit aim of providing such students with adequate preparation in mathematics and science. In addition, courses associated with modern technology are not available; most courses, in fact, make little reference to technology at all.

In the lower grades, mathematics courses emphasize basic computational skills rather than interpretation and application. Science courses at those levels often are empty of content and, generally, do not build upon the work of previous grades.

Appropriate courses in modern technology are not available. Few systematic attempts are made to integrate learning in mathematics, science and technology. As a result, little coherent preparation is offered for the disciplinary courses (usually earth science and biology) encountered for the first time in the ninth and tenth grades. This condition is particularly unfortunate, because a wealth of information supports the conclusion that students who dislike mathematics and science courses in the early grades, or who receive inadequate instruction in those grades, are unlikely to participate effectively in upper level courses.

Instructional Approaches

In general, precollege mathematics, science and technology instruction has yet to take advantage of the advances in technology and behavioral science of the past 20 years. For example, computers provide an immense opportunity to develop curricula and instructional approaches that might motivate larger numbers of students and increase the flexibility of the programs available to them. Computers and other modern technologies are available in many U.S. schools, and imaginative uses are made of these instructional aids in individual classrooms. However, computer software is generally inadequate, and the full potential of these technologies for instruction has received little attention.

Considerable progress also is being made in research in math and science education. The cognitive sciences are providing a wealth of informatin on the way people learn. For example, knowledge is now available about the relative degree of abstraction that students of a particular age can be expected to grasp. However, such information has yet to be systematically applied either in the development of mathematics, science, and technology curricula, or in the training of teachers of these subjects.

Finally, there is evidence that many students who have an interest in mathematics, science, and technology are not being reached through instructional approaches currently used in the classroom. Whereas many students do not like school science—and form this opinion by the end of third grade—many do like the science and technology that they see on television. They also like what they encounter at science and technology museums, planetariums, nature centers, and national parks. Many of these institutions facilitate science and technology education with their own after-school, weekend, and vacation classes. In addition, many school classes make field trips to such institutions. Because these programs are apparently more appealing than school science offerings, the innovative instructional approaches used in them should be examined and, where possible, applied to the classroom setting.

Public Perceptions and Priorities

Largely, public schools reflect, rather than determine, public perceptions and priorities. The condition of mathematics, science and technology education reveals an apparent misperception by the public that adequate course work need only be provided to students preparing for college-level study in these fields and that these courses are unnecessary for other students. This is consistent with the broader perception that excellence in science and technology is vitally important to the Nation but that it can and should be left to the experts. Thus, its pursuit has little to do with the day-to-day concerns of most people—except when major news events such as a nuclear reactor accident or a space shuttle launch intrude. This misperception about the mathematics, science and technology training needed by students in our schools is tragic for our society as a whole.

Yet, a reasonable fraction of the adult public is interested in science and technology. This is evident from the recent popularity of science magazines for nonspecialists, quality television and radio programs (particularly in the public media), and science and technology museums. Although a large fraction of the public enjoys science and technology, it appears that many consider school mathematics, science, and technology as isolated from the real world and not essential for most students.

That misperception is part of a public view that the aims, substance, and quality of public education do not reflect the considerable economic, social, and cultural changes that have occurred in this country since the late 1960's. Today, an increasing percentage of the work force is concerned with the retrieval, processing, and transmission of information. Yet, public school mathematics and science courses are, at best, only peripherally concerned and preparing students to work and live in a society that concentrates on such tasks.

Apparently, no consensus has been reached that the future prosperity and international position of the United States depend critically upon broader public attainment in mathematics, science, and technology. In addition, there is no consensus that high quality mathematics, science, and technology education is a matter of national concern, transcending state and local interests and responsibility. Mathematics and science requirements both for high school graduation and for college entry have generally declined over the past 15 years. Although there are some encouraging signs that this trend is reversing, only about one-third of the Nation's 16,000 school districts require more than one year of high school mathematics and one year of science for graduation.

National Science Board Commission

The absence of a national consensus on the importance of mathematics, science, and technology education for all citizens may be the central cause of the critical problem facing our educational systems. A broad national effort is essential. The National Science Board Commission on Precollege Education in Mathematics, Science and Technology has been established to address this condition. The Commission will define, over the next year, a national agenda that should provide an action plan for all sectors of society to use in the achievement of the three important educational goals outlined in the introduction to this report.

Sources

The data appearing in this report have been drawn from the sources that follow. Specific citations and additional references may be obtained on request from the office of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology.

1. National Science Foundation and Department of Education. *Science and Engineering Education for the 1980's and Beyond.* Washington, D.C.: U.S. Government Printing Office, October 1980, primarily Chapter V.
2. National Science Foundation. *Science and Engineering Education: Data and Information 1982. A Report to the National Science Board Commission on Precollege Education in Mathematics, Science and Technology* (NSF 82-30).
3. Papers presented at the National Academy of Sciences' Convocation on Precollege Education in Mathematics and Science, particularly Paul DeHart Hurd, "State of Precollege Education in Mathematics and Science," (May 12-13, 1982).

Mr. **Walgren**. I know that it may be difficult to be totally specific, but in your testimony you indicate that in the end of March you are going to be able to test out tentative recommendations at a public forum that will be held in Houston. Can you give us any indication of those tentative recommendations in specific form at this point?

Mr. **Coleman**. I can hint at some of them, but you have had experience in leadership, and unless you can have the members of the Commission agree with you as chairman, you don't put yourself out in front.

But, having said that, certainly anyone who reads has to be interested in the extent to which computers and other types of technology are here and are playing an increasing part. Certainly we are examining closely just how they can be used to help precollege education.

Second, we know that there are many teachers in the school system through no fault of their own who don't have the training to be able to give the type of science and mathematics, teaching required today, and we hope to make recommendations as to how we can speed up the training process.

We have considered, and we are more than just toying with the idea that this is an issue in which the business community and the military should be as interested as we are, if not more so. Is there any way that we can borrow some of those resources and put them in the school system to do some of the teaching until such time as the professional teachers have acquired this additional skill?

Mr. Chairman, I am pretty sure you and the other members all realize that in this country we still have a great disparity in what various school districts are able to offer to the children. We are trying to find out how we can overcome that disparity because the economic conditions in all places in the country are not the same.

Although it may be unpopular, we are thinking about the idea of devoting more time to handle this problem than is available in the school day to day? That may mean teachers will have to work longer days, and there may have to be more people involved.

We also, in our hearings and deliberations, have come to the conclusion that perhaps the drain of teachers into the business community and elsewhere merely because there is more pay could be avoided if their jobs in the school system were made more desirable and more attractive.

We are trying to come up with ideas that will make being a schoolteacher, particularly at the precollege level, as attractive today as it was 50 years ago when not you, Mr. Chairman, but maybe other members of the Committee had teachers who were really committed and who inspired us to do what we had to do to serve the country. Those are the types of ideas that we are trying to come up with.

Mr. **Walgren**. You mention in your testimony, as part of the second phase, that you have been looking at a range of model programs which could be broadened to other settings. Can you give us a survey of some of the particular programs that the Commission has looked at at this point and that they find very positive?

Mr. **Coleman**. Yes, but I would like to have the privilege of supplementing it by sending you a letter within 24 hours, spelling out all of the programs that we have looked at.

I think that would be very important. We are fortunate to have as co-chair Cecily Selby who, as you know, has been the leader in one of the most exciting programs in North Carolina. We have looked at that program. We also went to Atlanta, Ga. Under the leadership of Mayor Young and Governor Busby, we had an opportunity to look at several programs in Georgia where students are coming from all over to get the advantage of exciting training.

In North Carolina, Governor Hunt had the foresight to begin to develop educational programs. We have had the opportunity to look at programs in and around Raleigh, where teachers have provided a type of teaching that we think must be done for the student.

Congressman Brown, we haven't had the opportunity to get to California yet, but I am pretty sure that some institutions there are doing the same type of thing. I would like to supplement my remarks by letter in greater detail.

Mr. **Walgren**. We would appreciate that very much. Any specificity that you would like to elaborate on would be very helpful to the committee. Feel free to give us as full a written supplement as you feel appropriate.

Mr. **Coleman**. Having said that, will you give me 48 hours to get it to you rather than 24?

Mr. **Walgren**. I am sure from our point of view you can have a week and more. So feel free to take a little time and give it some considered thought.

Mr. **Coleman**. When I was a cabinet officer, I realized that if I could get things up to the Congress quick enough, the Congress did pay attention to them and Congress did think about them. Therefore, I am trying to get them up there as soon as I can.

[The information follows:]

NATIONAL SCIENCE BOARD COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

Listing of Programs and Activities Reviewed

The following is a representative listing of activities and programs that have been reviewed so far by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology. This list is organized according to the sector playing the major initiating or management role, although many programs involve partnerships among multiple groups or sectors.

Federal Government

Many of the programs/activities listed below were supported by Federal funds. In addition, the Commission has discussed precollege education issues and perspectives with representatives of the Executive Office of the President (OMB and OSTP) and with congressional staff members. The Commission has received reports on past and planned programs of the National Science Foundation and the Department of Education.

State Governments

Arizona: Governor's Six-Point Program for Academic Excellence in precollege mathematics, science and technology, as seen by Governor, State legislators, State Board of Higher Education, State School Boards Association.

California: Governor's Investment in People program, to strengthen math, science, and computer instruction in elementary and secondary schools. Includes demonstration projects, summer institutes, curriculum efforts.

Delaware: Governor's Task Force on high school graduation and university entrance requirements in mathematics and science. Jobs for American Graduates program, involving customized training for specific jobs, developed through committee of corporate and educational leaders.

Florida: Governor's Commission on Secondary Schools, which has recently issued a report with recommendations, including for teacher training and student incentives. House Speaker's recommendaitons to Florida legislature in this area.

Iowa: Ad-Hoc Education Committee of the Iowa Academy of Sciences, with recommendations to Governor concerning precollege education.

Louisiana: Louisiana School of Math, Science and the Arts, a public, residential, coeducational high school for exceptional students, established by State legislature in 1981.

Maryland: Education Committee of Governor's Science Advisory Council, which is examining mathematics and science programs at the precollege and university levels.

Maine: Governor's Commission to improve quality of labor force, from entry level to professional engineers.

Minnesota: Minnesota Wellspring, a coalition of state government, business, labor, education to improve technological/economic strength.

Mississippi: Governor's Comprehensive Plan to upgrade public education.

New Jersey: Business/Industry/Science Education Consortium.

New York: Center for Learning Technologies, established by State Department of Education in Spring 1982.

North Carolina: North Carolina School of Science and Mathematics, a public, residential, co-educational high school for juniors and seniors with exceptional ability and motivation, established in 1979, by intiative of Governor, funded by state legislature. Recommendations of Governor's Task Force on Science and Technology. Recommendations of North Carolina Board of Science and Technology and State Department of Public Instruction on improving the quality of science and mathematics education in the public schools.

Pennsylvania: State Department of Education's summer programs at Carnegie-Mellon University for superior science students at the sophomore and junior high school level.

Rhode Island: House resolution in state legislature requesting Board of Regents for Elementary and Secondary Education to study feasibility of state school for mathematics and science students. Governor's proposals for forgivable loans for eventual mathematics and science teachers.

South Carolina: Superintendent of Education's proposal to add science to State's "Basic Skills" list and establish special math/science teacher training programs.

Tennessee: Governor's proposal for Master Teacher program to provide merit pay, based on legislature's Tennessee Comprehensive Education Study, also upgrading high school math and science requirements.

Texas: Essential Goals for College Success project of Texas Commissioner of Higher Education. House Bill #246 to restructure K-12 curriculum with increased math and science emphasis. Workshop on Math/Science Teacher Shortage in Texas, sponsored by Texas Education Agency, Coordinating Board, and Southwest Texas State University.

Virginia: Governor's Task Force on Science and Technology, of which one objective is to determine education needs for developing human resources in science and technology.

Washington: Governor's Committee on High Technology Training and Advancement, which has issued recommendations.

Southern Regional Education Board: "Need for Quality", a report of SREB Task Force on Higher Education and the Schools.

Education Commission of the States: A report "The Information Society: Are High School Graduates Ready?" presenting results of the National Assessments, with recommendations for change at the precollege level. A special briefing to the National Governors Association Annual Meeting, August 1982, titled "Education for a High Technology Economy," with recommendations for state-level action. Advanced Leadership Program Series (ALPS).

Local Governments/School Districts:

Mesa School District, Arizona: District has been selected as one of top 12 in the country in elementary school science programming by NSTA.

Denver, Colorado: George Washington High School, with an extensive program in computer mathematics, allowing students to progress from computer literacy to writing programs.

Washington, D.C.: Six new high school career programs initated in cooperation with private industry support, including engineering, information technology, and the health sciences.

DeKalb County, Georgia: Fernbank Science Center, a facility designed to provide mathematics and science experiences for students from K-12.

Chicago, Illinois: Chicago Adopt-a-School program and local MATHCOUNTS, both pioneered by the Board of Education in the last two years. Pre-Algebra Development Center, recipient of Educational Pacesetter Award.

La Grange, Illinois: Lyons Township High School Computer Literacy Project, introducing teachers and students to a range of instructional uses of personal computers.

Houston, Texas: Houston Second Mile Program, involving merit pay for teachers, as well as many other initiatives.

Fairfax County, Virginia: Elementary school science program, providing science education for all elementary students.

Milwaukee, Wisconsin: High School Unlimited Program, in which each of the city's high schools has it own unique career/skill focus.

Institutions of High Education

New Jersey Institute of Technology: Precollege Institute in Mathematics, Science and Engineering, designed for secondary students and teachers.

City College of New York: Precollege mathemeatics and science outreach program.

University of Maryland: Institute for Mathematics and Science, for secondary students.

Duke University: Programs for gifted and talented and pre-engineering, secondary students.

College of Charleston: Mathematics and science program for secondary students.

University of California, Berkeley: Project EQUALS, developed at the Lawrence Hall of Science, providing inservice programs for teachers, counselors, and administrators, serving grades K-12, with emphasis on attracting and retaining women and minority students.

University of Arizona: Department of Mathematics' innovative program with high school teachers. Ad-Hoc Committee on Mahth/Science Education, to coordinate intra-university programs and outreach with precollege and business communities.

Arizona State University: Task force on implementation of Governor's Six-Point Program for Academic Excellence. College of Education's Program for Computer Literacy. College of Engineering's Center for Engineering Excellence, jointly supported by industry, and summer programs for women, minority and gifted high school students to encourage engineering careers.

University of Kansas: Career-Oriented Science Topics for Elementary and Middle Schools (COMETS), designed for use in grades 5-9 to supplement science and science-centered language arts courses.

University of Wisconsin: Multiplying Options and Subtracting Bias, an intervention program designed to eliminate sexism from mathematics education.

Atlanta University: Resource Center for Science and Engineering, provides training, facilities, research and other opportunities for the Southeastern Region.

University of New Mexico: Southwestern Resource Center for Science and Engineering, provides training, facilities, research and other opportunities for the Southwestern Region.

Mount Holyoke College: Summer Math program, to prepare high school women for successful study of mathematics at the college level.

Simmons College: Dreyfus Institute on High School Chemistry, training master high school teachers, primarily in chemistry, to conduct inservice workshops in their school systems.

Professional Societies/Associations

National Science Teachers Association: Project on "Search for Excellence in Science Education," examining outstanding precollege science programs throughout the country and analyzing them to identify elements responsible for success.

National Association of Secondary School Principals: Has surveyed and reported on "New Requirements by the State Universities."

National Association of Biology Teachers: Is sponsoring an annual awards program for oustanding high school biology teachers.

American Association for the Advancement of Science: Has established the Coalition for Education in the Sciences, to get AAAS members directly involved with schools, with developing resource materials, and with increasing science and technology understanding in local communities. A collaboration with the Association of Science-Technology Centers, including financial support from Phillips Petroleum and Standard Oil of Ohio.

Society of Sigma Xi: Awards program for excellence in science teaching, using its system of local chapters.

National Society of Professional Engineers: Initiated MATHCOUNTS, a national tournament to increase public awareness of the importance of mathematics and to increase interest and motivation of 7th and 8th grade math students. Involves collaboration and support of many associations.

Association of Science-Technology Centers: Members conduct numerous programs both inside and out of the schools, for teachers, students, and general public.

American Chemical Society: Has established an office devoted to the teaching of chemistry at the high school level, and is developing supplementary curricular materials for use at both the elementary and secondary levels.

American Society of Civil Engineers: Summer intern program for minority high school students, at Northeastern and Notre Dame Universities.

American Physical Society: Has opened an office in Washington and is following congressional and Executive Branch activities in area of precollege mathematics and science education.

Girls Clubs of America: Has initiated a program to link GCS national levek youth employment initiatives with interests in new technology.

Business/Industry:

Exxon Corporation: Supporting pre-engineering programs at 10 universities.

E.I. DuPont de Nemours and Co.: Supports pre-engineering programs at 15 colleges and universities, targeted for minority secondary school students.

Bell Laboratories: Summer Science Program, providing hands on experiences for minority students that have ccompleted the 8th grade.

Phillips Petroleum: "Search for Solutions", film series to augment science instruction in secondry schools, developed with Phillips support.

Multiple Collaboration Among Sectors

Children's Television Workshop: "3-2-1 Contact" is a television series aimed at interesting students in science and technology, developed with support from the Corporation for Public Broadcasting, United Technologies, Federal government.

Discovery Place: Non-profit organization providing curriculum-related activities for precollege students.

Junior Engineering Technical Society (JETS): A national youth activity, operating through student chapoters, to increase interests and aptitudes in math, science and technology. Cosponsored by several professional socieites and supported by industrial sources and the volunteer services of individual engineers.

Mathematics, Engineering, Science Achievement (MESA): Program to increase preparation of minority students in mathematics and science.

Philadephia Regional Introduction for Minorities to Engineering (PRIME): Identifies minority students in grades 7-12 with high aptitude in science and mathematics, and provides academic year and summer activities with specially trained teachers and staff.

Program for Rochester to Interest Students in Science and Math (PRISSM): Supports the purchase of innovative and stimulating curriculum materials for classroom and teacher training uses.

Southeastern Consortium for Minorities in Engineering (SECME): Including representatives of 21 colleges in 8 state, involves developing local projects to increase the numbers of minorities in the engineering profession.

Project to Increase Mastery of Mathematics in Connecticut (PIMM): Intended to raise the level of mathematics understanding and competence in order to help people achieve their vocational and professional goals, by doing job requirement analyses, and working with teachers and school counselors.

Comprehensive Mathematics and Science Program (CMSP): Designed to bring greater number of urban students into science and engineering professions.

Detroit Area Precollege Education Program: Designed to identify students with apptitude and increase interests in mathematics, science and engineering.

Mr. **Walgren**. I hope that we will be able to give it very complete attention. This is an area the committee is very interested in. As you know, we have stopped doing a number of things in the precollege education area in order to wait for the Commission's, recommendaton. So we are going to be very interested to see what new ground we break and what new directions we can come up with. Some of us feel that we have given up education programs in recent years in order to start out on this fresh review. So we are very interested in the results.

Mr. **Coleman**. Mr. Chairman, as you know, I am not part of the administration, I may be talking out of school, but I do think that the National Science Board and the Foundation both should be congratulated for taking the initiative to invest some of their scarce funds in this project.

I really think that if you are going to meet head-on the lack of scientific and mathematical training, that you first must start at the precollege level. The Foundation and Board should be congratulated for not waiting, either to be pushed by the Congress, or trying to get a special appropriation from the Congress, but taking some of their other money and investing in what I think is an important project.

Mr. **Walgren**. Following the committee rules, we will go by order of appearance. Therefore, the Chair will first recognize Mr. Brown.

Mr. **Brown**. Thank you, Mr. Chairman.

I want to commend Mr. Coleman on an excellent statement concerning the work of the Commission. I concur wholeheartedly with him that the Science Board and the Foundation is to be commended for initiating the Commission. I, of course, have to bear in mind the state of, I guess you might say, constructive tension that has existed between the Congress and the Foundation and the administration for more years than just this administration, over the question of adequate support of education in science and mathematics.

The question I guess I would like to raise with you and have you comment on is more of a philosophical question than anything else. You have recounted the concern of the Nation after Sputnik, and the great surge of activity with regard to improving our scientific, mathematical, and technical education. Then we have seen that initial impetus decrease. And the Commission has, of course, very well analyzed what has happened—the declining quality of science and math education. And the question comes to mind, why we cannot continue to hold in the forefront a desirable goal as we did after Sputnik, and to devote the necessary talent and resources to it?

We have qualified people in science and in education. I am inclined to feel, and maybe you could comment on this, that the problem is exactly as you expressed it on page 3, paraphrasing Clemenceau, that education is too important to leave solely to professional educators. This, of course focuses on the need for a dedicated and creative leadership which is able to keep in mind the total needs of the country and the proper balance to achieve those needs with then a total program.

The problem with the military, as Clemenceau well recognized, is that they become very expert at fighting the last war. And I am inclined to feel that our educators have somewhat the same attitude. That is, they become expert, maybe, at solving the last problem, but they don't perceive the dynamics that lead to the next problem that is coming along. And if science and math was important because of Sputnik, it is even more important today. Yet we don't seem to have perceived that.

Perhaps this puts too much blame on the educators. Perhaps they were absolutely doing the very best that they could, and they were let down. By who? By the lay board members that they were responsible to. By the national leaders that set goals for the country. I don't know. I am looking for some answers.

And I wonder if you might speculate on that a little bit.

Mr. COLEMAN. We are not going to fight the last war. And we are not going to spend our time trying to assign blame. But we are going to indicate what should be done today, and also suggest a mechanism so that this will not happen again. I agree with you that the country should keep education at the forefront. And the people who do that can't be the educators in a democratic society. It has to be the people. And it has to be the political leadership.

I think everyone at least once every 3 or 4 years should read an essay by Alexander Hamilton called "The State of Manufacturing in 1789." Using his wonderful brain, he spelled out what the United States would have to do to become a first-rate country. He emphasized teaching, education. He also emphasized the building of highways—The reason I read it the first time, being Secretary of Transportation, was that I could use that part to help to defend my own budget.

But I do think that the Nation must be aroused and should continue to be aroused. I think it is really the people who must do it in our democratic society. Sputnik contributed to arousing the public. Another thing that caused the public to examine the school system was the civil rights movement. Fortunately or unfortunately, we have run out of some steam on both of those issues.

And now we are facing an 11- or 12-percent unemployment, a $200 billion budget deficit, and some of the great automobile companies are joining up with the Japanese. I could make a whole list. It is not because we don't have the talent in this country, but the talent has not been educated properly.

I assume that is the reason why this committee is stepping up to the issue and is going to do something about it. I hope we can provide you with material to help you. It is very important to do so.

Mr. BROWN. That is an appropriate comment. The committee will do something about the problems of education. There are other problems that face us, as you have just indicated. We have had a decline in manufacturing, loss of markets, sometimes not due to lack of adequately trained scientists and engineers but to other phenomenon, such as a concentration on, we will say, shortrun profits versus the need to look at the long range need for development.

There is another aspect which I will just touch on briefly. Yesterday I had a visit from a Swedish group that is looking at some of the changes being produced by science and technology. And I understand they visited IBM and maybe had a talk with Dr. Lou Branscomb before they came up here. But the chairman of that group made a point which perhaps we have neglected over here. He kept mentioning it. That is, what is the purpose of all this science and technology?

In Sweden they seem to have recognized that the fundamental purpose is to create an improved quality of life for their citizens. That is a rather comprehensive kind of a goal which we don't think about over here too much. It is not the responsibility of leadership, really, to make utopian plans about the quality of life. And to inspire the people. At least we don't conceive of it. Our main job is to get elected just like Lou's job is to make a bigger profit next quarter for IBM. We lack that encompassing and inspiring goal which seems to be necessary to achieve quality in any activity.

I don't know how we are going to approach that and I don't expect you to have an answer to it. But if the Commission can come up with something, it would be greatly appreciated.

Mr. COLEMAN. We will certainly try. But I don't want to be too pessimistic. I think that the American people do have great ideals. And there are people in the country who, from time to time, articulate them. Sometimes their voices are crowded out. But if and when the right opportunity comes, there are people who articulate these goals. The fact that you have people involved in the National Science Foundation is one. The fact that you have Congressmen who may not find this to be the sexiest issue for them, but they think it is so important that they do devote time and effort to it.

The real question is, how do you galvanize all the resources out there now when the country has such a need for them? How do you do it short of a crisis such as a war? How can you do it when you don't think that the only threat you face is the Soviet Union? And how do you increase the quality of life for all our people? That is what we ought to be about.

Mr. BROWN. I am very pleased that we have a Commission with the quality of leadership that you represent, attacking this problem. I may suggest to the Board one or two other areas in which they ought to set up similar commissions in the future.

Mr. COLEMAN. That reminds me. When Mr. Lincoln was President, Great Britain did something. And his Secretary of War said, "Why don't we call a war on them, too?" And Mr. Lincoln said, "Gee, just one war at a time." So let us try to finish this problem.

Mr. WALGREN. Thank you, Mr. Brown.

Mr. Bateman.

Mr. BATEMAN. Thank you, Mr. Chairman.

Mr. Coleman, let me begin by saying that I am sure all of us agree that you are to be commended for extending your very long and distinguished career in service to the public interest in America by what you are doing now. Beyond being commended for it, I think it is only fair to point out that we are, in this country, continuing beneficiaries of that service. And your being here today and what you have been involved in is just another demonstration of the value of your participation in the larger concerns of our society.

I would like, if I may, to offer some comments and to seek your reaction to them. And the comments are inspired in substantial measure, I guess, by going through the report of the National Science Board where you make some specific comments on contributory problems within the larger dimension we are discussing, and particularly as it relates to teachers.

In the report, and this is page 4, you point out the deficiency in numbers of those who are in the precollege system, teaching math and science. That is a deficiency in gross numbers, even in terms of our present condition, and that is in the context that there just isn't enough going on out there to start with. But even in the present context, there are not enough teachers; 50 percent of those teaching, uncertified in their fields. To me, a larger figure that seems to cut against all that we are now recognizing and trying to do is that some 25 percent of those presently teaching in math and science anticipate or indicate that they expect to leave the field. We are not going to solve the problem by losing those already in it, especially when I think all logic suggests that those we are losing are probably those most qualified and are therefore in a better competitive position to go out into the private sector or to gain greater remuneration that comes with their superior training.

All of this comment is by way of a concern that, even with the bill that we marked up here in committee earlier this week addressing these problems, and I think every person on the committee shares the view that they must be addressed, we have perhaps held back in one area that is so logically important to a resolution of the problem, and so clear because maybe there is some pain or difficulty associated with it, politically or otherwise, the problem being we are not doing those things necessary to create the incentive for the competent and the dedicated teacher in science and mathematics who is already in the field, or to attract those of similar quality, to get into the field.

And in my view, over time that situation can't be improved unless there are some economic incentives to retain the best that we now have and to attract larger numbers in the future. Do you feel that there is some merit to your Board speaking to the necessity for incentives in teacher compensation, rather than what has become characteristic of most school systems of across-the-board increases for everyone in the system regardless of the perception of their competence, ability, dedication and training?

Mr. COLEMAN. That issue is a very important issue. It is under active debate within the Commission. And the Commission is going to come up with a recommendation. It may not be the most popular one, but we intend to come up with a recommendation. We do think in part the problem is money. But in addition, it is in part having an atmosphere that will continue to attract teachers to teach and to stay in the system.

We will also think that maybe one of the ways of helping us solve the problem in the short run might be to develop some system where industry would lend for an hour or two teachers to teach particular skills within the school. The one thing we don't want to do, because we think it really doesn't serve the public interest, is to make this 18-month study, write a report, and the only thing you see in it is that if you spend *x* million dollars more, you will have a better program.

We really want to try to tell you exactly what you have to do, and we think we have an obligation to say something other than, well, if you appropriate more money, you may get a little better product.

But I agree with you. You have put your finger on one of the most important factors. And you have to realize at the same time you talk about needing people who can teach and understand mathematics and science, you can't develop a society that is illiterate in foreign language. I know all of us probably ought to be somewhat embarrassed when we go abroad. We walk in the room and we immediately start speaking English. Other people speak German, French, Japanese, or Chinese, and there are very few Americans who can shift and speak in the foreign language.

So I really think, and the reason why I quoted what Governor Evans said, we are not going to say take all your money and effort; do nothing but teach people mathematics and science. We also need English, we need foreign languages, we need other things. We intend to try to meet that issue head on, and we may irritate some of the groups that represent teachers and look for, perhaps rightly, across-the-board raises.

Mr. **Bateman**. I don't offer comments I have made in the context that there is something inequitous about the orthodox point of view among the educational associations and their general perceived thinking on this. Once upon a time I was a classroom teacher, so I am very sensitive to how poorly they are paid across the board and how much increased teacher compensation is necessary.

I applaud your willingness to confront this proposition. I think it is one that is seriously necessary. Let me also hasten to add that I don't have a simplistic view that, if we just have merit pay for math and science teachers, these problems would disappear. They are much more diverse. I think we are in need of an attitudinal change on the part of our society to the importance of the subject matter, not merely from the aspect of having competent scientists who go on to win more Nobel prizes than anyone else, but a diffusion of funding, at least on an elementary basis, of the principles of science and mathematics among the general population.

I again applaud what you are doing. I am sure we will all look forward to further recommendations from the National Science Board and certainly wish you well in what you are doing.

Mr. **Walgren**. Thank you, Mr. Bateman.

Mr. Skeen.

Mr. **Skeen**. Thank you, Mr. Chairman.

Mr. Coleman, I want to compliment you on the presentation that you have made and the job that you are trying to do because I think you have monumental difficulty in moving in that direction. Given the 16,000 school districts that we have in the United States and the autonomous kind of character we try to maintain in our school systems, it is extremely difficult for us to view any kind of change, particularly in dealing with the professionals in the educational system, and effect that kind of change.

We have talked a lot about Sputnik this morning and how we reacted to that. We seem to like to do this in American life very often. Every time something occurs we react by going to the extreme, one side or the other. We are doing that today in science and mathematics. All of a sudden it has dawned on us that we have a decided paucity of this kind of professionals and we need them very badly. Now we want the school systems to react to it by immediately "let's flip the switch and turn them on."

I think the heart of what you are saying is in your interim report on page 7. You said during the first 6 months of its work the Commission observed a marked increase in concern about precollege mathematics, science, technological education. However, there is not yet an agreement about the particular changes that should be made and who should effect them, or how the changes should be best implemented. That is the question I would like to ask you.

I know that you have these task forces set up. How well received and how cooperative do you find the atmosphere amongst professionals in the educational field? I know it is very difficult. Who are the core representatives of this group that you must deal with to effect a rapid change in direction in the way the school systems work?

Mr. **Coleman**. We are fortunate to have on the Commission itself two teachers active in the school system. Obviously, they educate us on how you approach people who are part of the system. In large part it depends upon getting the school boards to recognize that this is important and, I think that is happening in the country. The Governor of almost any State today realizes that if he or she is going to keep the jobs in that community that it must have a better school system.

And as you know better than I do, what really moves this country is an aroused public opinion on any issue. And I think that we have to somehow arouse that opinion. That is the reason why we feel, as we go through this process and come up with our own understanding, it is equally important that we make other people part of the process.

As you remember, in those days when we had a good bipartisan foreign policy, it was because we had Presidents who would come up and talk to the Congress, even those in opposition, and get them to agree. Someone said, "Don't have me there when you are going to launch the ship, if I am not there when you lay the keel." We hope we can do the same thing by talking to the teachers to get them interested.

We also have the advantage of having on the Commission some of the users of the system who are active in business and the military.

Mr. **Skeen**. Do you find an air of enthusiasm for this kind of change and reaction?

Mr. **Coleman**. Oh, yes, there is no doubt about it, I think the public today recognizes there is a deficiency, and something has to be done. Hope that this Commission has the ability and foresight to be able to master that feeling and to come up with the correct recommendations.

Mr. **Skeen**. I also noticed that in this particular portion of your report it said that you have not reached an area of agreement on what the goals are that you want to achieve. I know it is very early in this thing; however, do you find some areas of agreement on what the goals should be? At least to get some refinement of where we are trying to go?

Mr. **Coleman**. We are in the process; the Commission is not unified. Speaking for myself, I hope we will set a time certain by which the problem should be solved. The figure in my mind is 5 years. In 5 years you ought to be able to do what is needed and the school system ought to be functioning the way it should be.

Mr. **Skeen**. I think that is very realistic. I want to share with you, too, your comments on lingualism amongst Americans. The definition of what is trilingual: a person that speaks three languages. What is bilingual? That is a person who speaks two. What is monolingual? That is an American.

Thank you very much.

Mr. **Walgren**. Thank you, Mr. Skeen.

Just one other thought, that is, that I suppose it is not a new thought that the more things change the more they remain the same. And I do appreciate the role of a clean break in starting new programs and in initiating new directions. At the same time, as I say, I often wonder what we are giving up when we totally break with the past. Is there anybody on the Commission that is looking at what we do through the National Science Foundation in the education area?

I know, for example, one of the major thrusts that you are looking at is how do you broaden the appreciation of science. And we did have a program to do that that has zero dollars in it this year. And it has zero dollars in it largely because we wanted to stop, and the Commission was in a sense the mechanism by which we stopped, or it was what was given in exchange for stopping.

Is there any ability of the Commission to look at what we were doing, and if it is true that we are going to be recognizing the validity of what we did do, to make recommendations or recognition of the value of those programs so that we can have as short a hiatus in valuable programs as possible?

Mr. **Coleman**. We are quite aware of that. We realize that often the resources available in the past, if the work is begun again, may well solve the problem. As Bert Lance said, if it works, don't try to fix it. Just make sure it keeps on working. We are certainly well aware of that.

Mr. **Walgren**. When will your final report be completed?

Mr. **Coleman**. October 1983. We will meet that deadline.

Mr. **Walgren**. Are there any more interim reports expected?

Mr. **Coleman**. We have had four meetings and we have two reports. I would think there will be another interim report. If not, I would undertake the responsibility of briefing your staff as to where we stand so you will be kept aware of the type of thinking we are doing.

Mr. **Walgren**. Well, we would appreciate being kept informed. And I would ask you to think about whether an accelerated report on past programs might be able to be considered by the Commission so that we would have whatever views are proper in those areas in the nearest term possible.

Mr. **Coleman**. I will commit myself to put that on the agenda of the Commission for March.

Mr. **Walgren**. Well, thank you very much, Mr. Coleman. We appreciate your time. We want to express the respect and appreciation of the public as a whole for people of your caliber serving on that Commission. I believe nothing could be more important. We are very pleased that you are the one that is involved in it.

Mr. **Coleman**. It is very kind of you to say so, Mr. Chairman. Thank you very much.

Mr. **Walgren**. Thank you.

We now turn to Dr. Knapp, the Director of the National Science Foundation. Dr. Knapp is appearing for the first time formally before the subcommittee in his new position as Director, although he is familiar to us through the efforts of Mr. Fuqua on the full committee.

We want to welcome also Dr. Lewis Branscomb, Chairman of the National Science Board, who is here accompanying Dr. Knapp today.

Welcome to the committee. Your written statements will be made part of the record. We welcome any later written submissions in further explanation or development of any points you believe the committee and the public should be apprised of as part of the public record. And with that, please proceed as you feel best to communicate your views to the committee.

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. LEWIS M. BRANSCOMB, CHAIRMAN, NATIONAL SCIENCE BOARD

Dr. **Knapp**. Thank you, Mr. Chairman.

I am pleased to be here for your first day of hearings on the administration's fiscal year 1984 budget request for the Foundation.

Today's hearings focus on science and engineering education and training, a subject of great current interest and concern in the Nation, the Congress, and the administration, especially as it bears upon the quality of precollege education today in the secondary schools.

The Foundation shares this concern and is moving in a concerted and deliberate way to develop a clear consensus on the nature of the problem and the strategies needed to alleviate it.

At this point I would like to turn to Dr. Lewis M. Branscomb, Chairman of the National Science Board. He will comment on the role the Board has played in setting the Foundation's budget strategy for fiscal year 1984 and the Board's part in developing a consensus for NSF's role in science and engineering education. Dr. Branscomb.

Dr. **Branscomb**. I would like to take a few minutes to touch on the highlights of the Board's involvement in this budget and on what it contains. I will paraphrase my prepared testimony, and then I will discuss specifically the issue of precollege science education.

Mr. **Walgren**. If I could note for the record that this is in contrast to the Board's involvement in the 1981 fiscal year budget. Is that correct?

Dr. **Branscomb**. No, sir. I would like to speak to that in due course, quite specifically. The Board was very active in 1981. I want to be sure this committee understands exactly the Board's activity.

Mr. **Walgren**. I would be interested.

Dr. **Branscomb**. We meet this spring under fortunate circumstances. Having listened to the President's state of the Union message, and having looked at the content of this budget, we can now say that the question of whether this country needs strong science and engineering capability, a well-educated group of specialists, and a generally skilled public, is no longer a partisan issue. On that question we are all together.

And the issue, if there is an issue, is only what is the best way to use the scarce resources available to us. What is the most effective way to move all those objectives ahead?

The Foundation's proper role, in the Board's view, is to support advances in science and engineering that lie beyond the horizons of most companies, to encourage the highest quality of education in science and engineering research, to practice such education in the colleges and universities, and to improve the teaching of mathematics and science in secondary schools where it can do so with high leverage and in support of community goals.

In order to accelerate the contribution of the resulting knowledge and skill to the economy and to the people, the Board also encourages close and voluntary collaboration between universities, colleges, and private companies. The Board has been active in all of those areas in this past year.

First let me say the Board is pleased that this budget will permit a balanced strengthening of all the fields of science, while it focuses on specific areas ripe for rapid advancement offering special benefits, if we are successful. Most important, this budget addresses urgent needs for the rebuilding of facilities, instrumentation, and equipment in the research laboratories of educational institutions.

The budget reflects Board efforts to give particular attention to several matters. In 1981 the Board devoted its primary policy development efforts to clarifying NFS's role in supporting science and engineering education, to the adequacy and emphasis of support in the social and behavioral sciences, and to the academic research community's needs for research instrumentation and equipment. The Board provided policy guidance to the staff in all three areas.

In August 1981, the Board adopted a statement of policy and program priority on science and engineering education, and it approved the same day the Director's implementation plans, which were quite specific.

This work provided the basis for the subsequent establishment of the Board's Commission and identified the kinds of program activities in precollege mathematics and science education appropriate for NSF.

Let me remind you again that, in August 1982, the Board and the Foundation submitted a budget which included funds for science and education. We approved a policy statement on the proper role of the Foundation in science education. And we approved an implementation statement that contained both the Commission and specific activities.

If the chairman will pardon me for differing with the comment he made earlier, from the Board's point of view, we did not stop science education efforts in order to start the Commission. We did not intend that efforts should stop.

On the other hand, I do not fault a judgment that says that efforts had arrived at a poor pass at the time they were stopped. The science education program had been declining for many years; it had become controversial; it was fragmented into 27 line-items. We did need a fresh start.

But it is wrong to say that either the Board or the Foundation set up the Commission for the purpose of defraying pressure on us to be specifically active in a programmatic fashion. As a matter of fact, quite the contrary. We established the Commission in order to generate that pressure. But we felt the pressure ought to be generated on the citizens of this country by themselves, not just on the Congress and the Foundation. Still, we recognize the latter has been a consequence; from my point of view, a desirable consequence.

In 1982 the Board paid special attention to opportunities and policy issues in engineering, the plant sciences, computer-related research, and international sciences. Science education activities evolved as the Board's Commission on Precollege Education in Mathematics, Science and Technology went to work, having already established the policy statement and Director's proposed implementation.

The present budget request would permit a significant number of critical needs to be addressed. Let me give you some examples. First, a substantial portion of the new funds will go to modernization of scientific equipment. I believe Dr. Keyworth has used the word shabby to describe the state of many university laboratories. I certainly concur. A distinguished member of the National Science Board from the General Electric Co. commented that in his company, scientists are given instrumentation support in a measure that far exceeds the ratio of instrumentation support provided to NSF grantees.

We must rectify that condition. This budget goes a long way to do so, but the gap is so large it will take several years of increased support, per investigator, and across the board to new participants.

The field of mathematics has been neglected for a number of years, and the field historically has been a magnet for the most brilliant young students. But the vitality of the field has suffered and needs some rebuilding. So, too, selected areas in the social sciences, identified in the Board's policy statement last year. Those areas are addressed in the fiscal year 1984 budget.

Plant biology has been recognized as an opportunity area for American science that can have only scientific and economic benefits of a high order. The molecular biology advances of recent years provide the point of departure, but cellular and developmental biology and the biochemistry of plants are receiving attention from only a handful of leading laboratories.

Yet the new scientific findings from these laboratories encourage the belief that a new knowledge base for a revolution in agriculture and in natural products technology can be ours, if we go after it. The anomaly of this small effort in the face of exciting research possibilities results from two facts: First, the manipulation and cloning of plant cells are often more difficult than for living animals; techniques are not yet fully available. Second, research funding has centered principally on health-oriented agencies which have not given as much attention to this field as they should.

Engineering is in the middle of a revolution, brought about by new technology—the computer, thus simulation; graphics design and robotics—and by a new urgency (the demonstrated ability of Japan to use a large, well-trained engineering force to produce goods of higher quality and lower cost than many U.S. firms provide.)

Concurrently, the Board sees striking reasons to invest in research in computer science, in electrical and computer engineering, in the application of new information technologies, and in addressing the most urgent problems in education in computer skills.

These examples will serve to illustrate something of the nature of the Board's impact on budget priorities. The process begins each year in the late fall and winter when teams of Board members discuss priorities with the Director and with Assistant Directors and other senior staff in the Foundation. The Board also looks at special issues such as the state of science education, capital facilities, and international opportunities.

In February and March, the Board discusses long-range plans and program priorities, as it is now doing, anticipating the fiscal year 1985 budget. Furthermore, the most important issues that emerge make up the agenda for the Board's June meeting, which is devoted exclusively to full discussion of two or three major topics.

All this work is reflected in the NSF's budget submission to the Office of Management and Budget in August. The Board and Director submit a budget they both support. This work is, of course, done within the policy framework established by the President and the Congress. The budget request to Congress follows from the President's final decisions, as he must meld NSF's budget proposals with those of the rest of the Administration.

Now let me turn to education in science and engineering. As I said earlier, the responsibility for college-level education at NSF is placed within the operating directorates. The Foundation continues to concentrate the majority of its resources on research in college and university laboratories, for there NSF not only finds superb talents willing to compete for support with their best ideas, but also by following this policy, NSF contributes to the training of some 10,000 graduate students in the most rewarding fields.

This student support complements fellowship support, which continues to be a vital component of the total strategy for providing the next generation of scientists and engineers. For fiscal year 1984, NSF is beginning a new initiative to further encourage younger faculty in fields reporting shortages of such faculty. Dr. Knapp will be discussing that initiative.

Two precollege initiatives will provide an important contribution to the encouragement of excellence in mathematics and science teaching and to improvement of the professional capabilities of mathematics and science teachers.

I won't comment about the dimensions of the problem; Secretary Coleman addressed them ably; all of us are familiar with the facts. The Board's Commission has been working to stimulate the broadest awareness of this issue and actions to address it. In my view and in that respect, it already has been successful. A torrent of activity now involves professional societies, business leaders, Governors, and especially the school systems.

One item that impresses me most, not only as an observer of the Commission's work but also as an individual in my company trying to help the educational system of the company, is the amount of ingenuity being brought to bear in different States, different communities, by companies, governors, and school systems. They are finding ingenious ways to get at this issue so that it captures the public imagination.

I urge strongly that we learn as much as we can about these initiatives. And that as the Federal Government tries to be as helpful as it can, it keeps its ability to respond, flexible and broadly based so that the truly local initiative can be pursued and so that it can effect its proper multiplying factor across the country.

As Mr. Coleman said, the Commission will complete its work in October, and the Board is arranging its own plans in an open process for all to see. As he said, quite rightly, the Commission intends to start discussing its own conclusions in public shortly.

That is entirely proper since it is important for us to know how the views developed in a consensus are accepted by all the different people in this country who must join forces if we are going to be successful. The Board itself is organizing its plans so that it will be able to act quickly on the Commission's recommendations.

One of the benefits of the Commission's doing its work in public and sharing its early thoughts about its recommendations is that the Board will be engaged in dialog on this issue in parallel with the Commission. In fact, the Board will devote much of its June meeting to the discussion of science education in order to be ready well in advance of October.

The Board believes, as it said in August 1981, that NSF can and must play a leadership and catalytic role in the national effort to solve this problem. This is an important subject on the national economic agenda; we are making a significant start in this budget.

Let me make two other points about the NSF program in fiscal year 1984, then I will stop. First, the Board's 14th Report to the President and Congress, which you recently received, is on the topic, "University-Industry Research Relations: Myths, Realities and Potentials." It describes a dynamic situation with a rapid growth of scientific and engineering collaboration, which surely will accelerate the evolution of new research ideas into the economy and help industry to be more innovative and competitive.

Even before the report was completed, rapid expansion in the number of such collaborations had been reported. NSF's early encouragement helped trigger this development, but we are not under any illusion that NSF caused it. It is driven by natural forces that will be good for both groups of institutions.

This phenomenon should make the Congress even more confident that the investment it makes in long-range university research will indeed be an investment in jobs and a better life for the American people. It is the dynamic coupling with the private sector that causes intellectual and educational investment to bear prompt fruit. I assure you that that coupling is strengthening rapidly.

Second, let me call attention to the Board's consideration of international science issues. Increasingly we need to help U.S. scientists get access to field sites abroad for scientific study; we need to be able to build collaborative relationships with the increasingly strong scientific groups in countries like Germany and Japan; and we need to be able to plan jointly major research facilities which are increasingly difficult to fund for the exclusive use of any one country.

The Board's policy statement of last September will guide the directorates as they take responsibility for both domestic and international aspects of their fields of science and engineering, with the help of the International Division of the Foundation and the guidance of the Department of State.

The Board does not expect the new way of managing to diminish the importance of international relations in science; indeed, the Board seeks to make them more tightly coupled to the U.S. interest in science, which includes the need for a free and productive world scientific community.

Finally, let me note that I really feel, as I said at the beginning, that a science policy—oriented to economic as well as national security goals—is emerging and is reflected in the plans of the Foundation. As a consequence, I feel more optimistic about the future than I have felt in quite a long time.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Branscomb follows:]

STATEMENT OF DR. LEWIS M. BRANSCOMB

Mr. Chairman and members of the subcommittee, I am Lewis M. Branscomb, Chairman of the National Science Board. It is my pleasure to appear before you today to discuss the authorization of the fiscal year 1984 budget for the National Science Foundation.

I will summarize the Board's role in the construction of this budget and discuss some of the Board's activities during the last year that have a bearing on the strategy behind this budget, the priorities in it and the policy issues that are attached to its implementation. I will be brief in order to leave as much time as possible for your questions.

The President's 1984 budget attaches a high priority to the task of strengthening the academic science and engineering base on which the nation's economic and military security depend. A very substantial increase in basic research funding is requested at a time when all of us are eager to see the federal budget gap closed and every unnecessary federal expenditure eliminated. I urge the Committee to authorize the full amount requested for the Foundation in this budget. In so doing, I assure the Subcommittee that the National Science Board has weighed very carefully the priorities in this budget and is persuaded that the investments proposed are indeed necessary. Furthermore, we are confident that the monies will be spent wisely, through the well-respected competitive review system that the Foundation has used for more than thirty years.

The people of this country are eager to see the economic vitality of the United States rekindled and agree with the President's emphasis on retaining leadership in science and technology as an important element of economic strategy. The private sector should be expected to make its own investments in research and development, production and service technology. The National Science Foundation's proper role is to support advances in science and engineering that lie beyond the horizons of most companies, to encourage the highest quality of education in scientific and engineering research and practice, and to help improve the teaching of mathematics and science in secondary schools where it can do so with high leverage and in support of community goals. In order to accelerate the contribution of the resulting knowledge and skill to the economy, the Board also encourages close and voluntary collaboration between university and private company researchers. The Foundation has been active in all these areas this past year. I will note the highlights. First let me speak to research priorities.

The budget reflects the emphasis that the Board has placed for several years on investments in equipment and people to work in the physical sciences and engineering. But we are pleased that this budget permits a balanced strengthening of all fields of science, while focusing on specific areas that are ripe for rapid advancement, that offer special benefits if successful, and that address the most urgent needs for rebuilding of facilities, instrumentation, and equipment.

The budget reflects Board efforts to give particular attention to several matters. In 1981 the Board devoted its primary policy development efforts to clarifying NSF's role in supporting science and engineering education, to the adequacy and emphasis of support in the social and behavioral sciences, and to the academic research community's needs for research instrumentation and equipment. The Board provided policy guidance to the staff in all three areas. In August 1981, the Board adopted a statement of policy and program priority on science and engineering education, and approved the same day the Director's implementation plans. This work provided the basis for the subsequent establishment of the Board's Commission and identified the kinds of program activities in precollege math and science education that are appropriate for NSF.

In 1982 we paid special attention to opportunities and policy issues in engineering, the plant sciences, computer-related research, and international science. Our work on science education evolved as the Board's Commission on Pre-College Education in Mathematics, Science and Technology went to work.

The present budget request would permit a significant number of critical needs to be addressed. Let me give you some examples: A substantial portion of the new funds will go to modernization of scientific equipment. The strategy of including these funds within the budgets of the several directorates will help ensure that the new funds go only where the merit of the proposed new work is very high. The new equipment will be applied in just those project areas with the highest potential for scientific payoff. This rebuilding of the universities' laboratories will have to be continued for a number of years before the level of modernization is even equal to that typical of industrial research. University laboratories, of course, should be working well beyond the forefront of industrial research; they should have access to even more sophisticated facilities and equipment.

The field of mathematics has been neglected for a number of years, and the field has historically been a magnet for the most brilliant young people. The vitality of the field has suffered and needs some rebuilding. So too do selected areas in the social sciences, identified in the Board's policy statement last year.

Plant biology has been recognized as an opportunity area for American science that can have only scientific and economic benefits of a high order. The molecular biology advances of recent years provide the point of departure, but cellular and developmental biology, and the biochemistry of plants are receiving attention from only a handful of leading laboratories. Yet the new scientific findings from these laboratories encourage the belief that a whole new knowledge base for a revolution in agriculture and in natural products technology can be ours. The anomaly of this small effort in the face of the very exciting research possibilities results from two facts. First, the manipulation and cloning of plant cells are often harder than for living animals; techniques are not yet fully available. Second, research funding has centered principally on health-oriented agencies, which are, because of their roles and missions, more interested in human physiology than in plants.

Engineering is in the middle of a revolution, brought about by new technology (the computer, thus simulation; graphics design and robotics) and by a new urgency (the demonstrated ability of Japan to use a large, well-trained engineering force to produce goods of higher quality and lower cost than many U.S. firms provide.) Concurrently, the Board sees striking reasons to invest in research in computer science, in electrical and computer engineering, in the application of new information technologies, and in addressing the most urgent problems in education in computer skills.

These examples will serve to illustrate something of the nature of the National Science Board's impact on budget priorities. The process begins each year in the late fall and winter when teams of Board members discuss priorities with the Director and with Assistant Directors and other senior staff of each of the disciplinary areas. We also look at special issues, such as the state of science education, capital facilities, and international opportunities. In February and March, we discuss long-range plans and programs priorities. furthermore, the most important issues that energy make up the agenda for the Board's June meeting, which is devoted exclusively to full discussion of two or three major topics. All this work is reflected in the NSF's budget submission to the OMB in August. At that stage, the budget is jointly recommended to the President by the Director and the Board as I said. This work is, of course, done within the context of the overall policy framework established by the President and the Congress, and the final budget request to Congress follows from the President's final decisions.

Now let me turn to education in the sciences and engineering. As I said above, the responsibility for college-level education is placed within the operating Directorates. We continue to concentrate the majority of our resources on research in college and university laboratories, for there we not only find superb talent willing to compete for support with their best ideas, but, by following this policy, we contribute to the training of some 10,000 graduate students in the most rewarding fields. This student support complements fellowship support, which continues to be a vital component in the total strategy for providing the next generation of scientists and engineers. For FY 1984, we are beginning a new initiative to further encourage younger research faculty in shortage categories. Dr. Knapp will be discussing that.

Two precollege initiatives will provide an important contribution to the encouragement of excellence in math and science teaching and in improving the professional capabilities of math and science teachers. The dimensions of the problems facing the Nation's schools in these areas are now well known. The Board's Commission has been carrying out its work with the intent of stimulating the broadest awareness of this issue and actions to address it; it has been quite successful in my opinion. A great variety of activities, by professional societies, business leaders, Governors, and especially the school systems themselves are now being generated.

We expect the Commission to complete its work in October, and the Board is arranging its own plans to act quickly on the Commission's recommendations. The form of these conclusions should begin to become clear later this spring, for the Commission is carrying out its work quite publicly, encouraging feedback from citizens and teachers in the towns where the Commission meets. The Board believes, as it said in August 1981, that the NSF can and must play a leadership and catalytic role in the national effort to solve this problem. This is a very important subject on the nation's economic agenda; and I think we are making a significant start in this budget.

Let me make two other points about the NSF program in 1984. The Board's 14th report to the President and Congress (which you have recently received) is on the topic, University-Industry Research Relations: Myths, Realities and Potentials. It describes a dynamic situation with a rapid growth of scientific and engineering collaboration, which will surely accelerate the evolution of new research ideas into the economy, and help industry to be more innovative and competitive. Even before the report was completed, rapid expansion in the number of such collaborations has been reported. NSF's early encouragement helped trigger this development, but it is driven by natural forces that will be very good for both groups of institutions. This phenomenon should make the Congress even more confident that the investment you make in long range university research will indeed be an investment in jobs and a better life for our people.

Second, let me call attention to the Board's consideration of international science issues. Increasingly we need to help U.S. scientists get access to field sites abroad for scientific study; we need to be able to build collaborative relationships with the increasingly strong scientific groups in countries like Germany and Japan; and we need to be able to jointly plan major research facilities which are increasingly difficult to fund for the exclusive use of any one country. The Board's policy statement of last September will guide the Directorates as they take responsibility for both domestic and international aspects of their fields of science and engineering, with the help of the International Division of the foundation and the guidance of the Department of State. The Board does not expect the new way of managing to diminish the importance of international relations in science; indeed we seek to make them more tightly coupled to the U.S. interest in science, which includes the need for a free and productive world scientific community.

Finally, let me note that a science policy—American-oriented to economic as well as national security goals—is emerging and is reflected in the plans of the Foundation. I feel very optimistic about the future.

Thank you.

[Following is a letter sent from Dr. Lewis Branscomb, Chairman of the National Science Board to Dr. Cecily Selby, Cochair of the NSB Commission on Precollege Education in Mathematics, Science and Technology, summarizing the Board's point of view on the NSF role is science and engineering education.]

NATIONAL SCIENCE BOARD
WASHINGTON D.C. 20550

March 22, 1983

Dr. Cecily C. Selby
[illegible]5 Sutton Place, South
New York, New York 10022

Dear Cecily:

In our phone conversation last week I promised to provide you with a summary of the Board's current point of view on the NSF role in science and engineering education, particularly concerning its role in precollege education. This may be helpful as background for our joint meeting on May 18.

We had a discussion of this subject at our February Board meeting in preparation for testimony that I would give the following day before Mr. Walgren's Subcommittee on the NSF 1984 Authorization. This particular hearing, where Bill Coleman also testified, dealt specifically with the science and education issue and also focused on the precollege area.

Let me emphasize at the outset that the following summary should not be taken as an attempt to constrain the Commission's deliberations in any fashion. Rather, I would like to share our current views with the Commission to see how our perspectives mesh.

Our Board discussion last month did not attempt to define specific programs or projects to implement existing policies, since there are a great many such proposals now under discussion and we hope the Commission will provide us with a reasonably specific framework of advice within which specific programs and projects can be developed for the future.

What the Board did was review our earlier policy statement and some recent thoughts from both Ed Knapp and me. Putting the role of the National Science Foundation in precollege science education in a broader context, the Board informally concluded that:

- The Foundation should act in ways that utilize its unique talents and resources, utilizing the support and knowledge of the scientific and engineering community with whom the Foundation has worked successfully for over 30 years;
- The Foundation must continue to focus on research-level education because of the Federal Government's primary role in supporting basic research in universities and the Foundation's unique expertise in carrying out that role;

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- At the same time, the Foundation must seek to strengthen other aspects of scientific and engineering education, particularly precollege science and math education, on which scientific and engineering research depend;

- In selecting precollege science and math activities, the Foundation should seek those activities in which it can exercise relatively great leverage.

In reaching these conclusions, the Board considered the statutory authority and subsequent history and experience of the Foundation. Because this background may also be helpful in your own deliberations, let me provide a summary, as well as criteria that were considered for an NSF role.

The Foundation's role in precollege science education derives from our statutory authority, the things we do well, and our evaluation of priority needs for appropriate Federal activity within the scope of our statutory authority. I will consider each of these topics in turn.

Statutory Authority

Responsibilities for research are placed side by side with responsibility for programs "to strengthen scientific research potential and science education programs" in the first sentence describing our functions (42U.S.C.§1862, Sec.3.(a)(1)).

In addition, section (3) calls out specific authority to: "award scholarships and graduate fellowships" and "to foster...the use of computer and other...methods...for research and education in the sciences."

Finally, the statute says that "the Board and the Director shall recommend and encourage the pursuit of national policies for the promotion of basic research and education in the sciences."

Thus the conjoint responsibility in research and education is clear.

The statute is also even-handed and unspecific about the levels of education to which the Foundation should accord authority. However, the coupling of "research and education" suggests a priority for education that is associated with research training, in other words college and university level educational problems. Obviously the majority of the Foundation's educational activity in science and engineering is at this level. Our policy of investing primarily in university laboratories for the conduct of basic research is intended to assure the strength of the graduate schools of those universities. Our research grants provide financial support for over 10,000 graduate students, in addition to our fellowship program. Thus, our principal educational activity is at the post-kindergarten through grade 12 level.

However, it is very clear, from legislative history, from prior activities of the Foundation, and from the impact that an inadequate precollege educational system can have on college education and research capability that a significant priority must be accorded to science education at the precollege level.

National Science Board Policy

In the Board's statement of March 20, 1981, we said, "The Board can see a crisis coming of serious proportions" in precollege math and science education. While agreeing that public schools are primarily a local responsibility, the Board "is convinced the Foundation has an indispensable catalytic role it should not abrogate, even if the level of investment is severely curtailed."

On August 20, 1981, the Board issued its statement on NSF activities in Science and Engineering Education after careful study and deliberation.

We identified these priorities:

1. Unique responsibilities--
    a. Support for research level education.
    b. Evaluation and monitoring of the national science and engineering education system with respect to... human resources...to meet national needs in science and engineering education.
2. Leadership in identifying areas of special concern--
    To "encourage other agencies, state and local government and private organizations to meet those needs," and
3. Selected high-leverage activities--
    For NSF to "intervene in selected areas where significant improvement in educational outcomes is possible within limited investment."

The Director's implementation statement of the same date identified for the precollege area (with emphasis on setting examples and testing prototypes)

1. The Commission - as a means for taking a leadership role in a voluntary context and
2. Several specifics:
    a. Materials for science teachers to convey new knowledge and technology...
    b. Interaction between science teachers and.. colleges, universities and industries, and

c. Regional resource centers for needs assessment in-service training, encouragement of science interests in minority and women and local leadership development.

Based on these statements we believe there are some criteria that could readily be applied to NSF's precollege science education activities.

Criteria for NSF Role in Science Education

Primary and secondary education in the United States is a vast, decentralized enterprise. In terms of dollars, NSF necessarily will always have a small role, even within the context of the Federal Government. The following criteria can be inferred from this fact and from the statutory and historical role of the Foundation. NSF activities at the precollege level may not meet all of the criteria listed here, but should be selected and designed to meet as many of them as possible. An activity should:

- Exert high leverage. A corollary is that appropriated funds must be sufficient to ensure that the activity will have the intended impact;
- Demonstrate leadership in the national interest through example-setting, prototype testing, and the like;
- Take advantage of NSF's access to the Nation's laboratories, colleges, and universities;
- Be as flexible as possible in order to be receptive to new and unanticipated ideas, and encourage innovative projects involving qualitative improvements in science education;
- Be designed so that selection of individual projects is based on excellence and the evaluation of scientific merit is based on peer review;
- Promote the involvement of state and local governments, the private sector, and professional scientific and engineering societies and organizations.

Examples of Possible Program Activities

1. Leadership efforts, for example through the NSB Commission;
2. Stimulating the improvement of new materials to help teachers keep up with science and stimulate student interest;
3. Assisting institutions capable of assisting teachers both with materials, technology, and content;
4. Bringing public recognition to activities and programs in science education of unusual merit;

5. Assisting in the development of institutions, for example at the regional level, to provide scientific and technical support to science education;

6. Enhancing access of secondary schools to college, university, and industry resources in science and engineering;

7. Working with colleges, universities, and schools to facilitate cooperation at the high school/college interface;

8. Cooperating with the educational community to develop techniques for measuring educational achievement and the setting of educational goals and standards by states and communities;

9. Providing a flexible capability to respond quickly and effectively to opportunities to encourage innovative approaches to cooperation between schools, their communities, professional societies, businesses, unions and/or governmental bodies at all levels.

Examples of inappropriate roles for NSF would be:

1. Formula grants, money to relieve financial burdens on schools;

2. Formula-based salary increments for teachers;

3. Block grant support for teacher colleges.

Such activities are not necessarily wrong for the Department of Education; they are inappropriate for NSF.

Activities inappropriate for any Federal agency are:

1. Production and gift or sale of educational materials that are or readily can be available from private sources;

2. Setting mandated Federal standards of achievement in local schools; and

3. Dictating curriculum to local schools.

All of these examples I have given are consistent with Board policy and indeed are largely identical with the Board-approved Director's Implementation Statement of August 20, 1981.

They are also consistent with the views of the Senate Appropriations Subcommittee on HUD-Independent Agencies received February 17, 1983, from Senator Garn.

I hope that the information about recent Board consideration of science education is useful to you. Speaking for the other members of the National Science Board, I want to thank you and the other Commissioners for the great dedication of effort you are making to this very important problem. Your efforts to date have already brought a great enhancement of public attention to this issue, which is now gaining the attention of the citizens of the Nation. We look forward to your recommendations and assure you that the Board will attempt to act promptly upon them.

Sincerely yours,

Lewis M. Branscomb
Chairman

cc: Mr. William T. Coleman, Jr.
Dr. Edward A. Knapp

Mr. **WALGREN**. Thank you, Dr. Branscomb. Dr. Knapp.

Dr. **KNAPP**. The educational base for producing the nation's future research scientists, engineers, and technicians consists of a continuum extending from primary and secondary schools through undergraduate colleges and universities to graduate and professional schools and on to postdoctorate appointments.

As students move through these institutions, their choices are influenced by the quality of the faculty and teaching and, later by the opportunities to gain firsthand knowledge of the research process. In a real sense, it can be argued that the entire budget of the Foundation serves to promote and strengthen science and engineering education.

I will describe in some detail how the Foundation's fiscal year 1984 budget request addresses the educational base. NSF's major responsibilities lie in graduate education and training in research which it supports through fellowships, stipends in research awards for graduate research assistants, and post-doctorate awards.

These responsibilities reflect the broad consensus developed in this country since the 1950's on the role played by the Federal Government in the support of long-term fundamental research and in maintaining the health of the basic research enterprise.

The training of graduate students through an apprenticeship system, working with university faculty who are themselves successful researchers, is an absolutely critical part of this enterprise. NSF also has a role, but necessarily a more selective one, in the area of precollege education.

Precollege education in the United States is a vast, decentralized enterprise with some 16,500 local school districts. Since the beginning of this republic, such education has been and remains a major responsibility of States and localities, reflecting the deeply held belief that education should be responsive to the needs and views of the local community and the family.

There has also been a considerable degree of Federal interest in precollege education. We Americans have long held the belief that a well-educated citizenry is the backbone of a democracy. To that concern we would add, today, the belief that a competitive, strong economy and a secure society depend on the quality of scientists, engineers, and technically trained personnel.

It is also true, however, that there has been much less consensus on the appropriate Federal role in precollege education, including precollege education in science and mathematics, than on the role of local communities.

As the members of this committee are well aware, the Foundation has operated a broad range of science education programs for many years. NSF concentrated on science curriculum development, on teacher training, and on the development of scientific manpower. There was general agreement at that time that such effort was an appropriate role for the Federal Government and the Foundation.

The potential for overlap between the then Office of Education and the NSF at the precollege level was easily resolved. The NSF would focus on science and operate mainly through the scientific community and through universities and colleges, the primary group with which it had constant interaction and which was the source of the most current scientific knowledge. It was NSF's comparative advantage, given its responsibilities for basic research. The Office of Education, in turn, would work mainly through State and local education systems and focus on the broad application of education.

Though the dollar magnitude of the Office of Education programs—not to mention expenditures by States and localities—far outstripped those available to the NSF, there was widespread agreement that NSF's activities were well-targeted, well-managed and effective in meeting their objectives. For relatively small amounts of money, NSF was able to have a substantial impact on precollege science education across the Nation.

In the 1970's, however, there was a reorientation of science education programs. Scientific personnel shortages were seen to be less acute. Emphasis was shifted to increasing the science literacy of all citizens and increasing the training opportunities for groups with low participation in scientific and technical careers.

By 1979, at NSF there were 28 different programs in science and engineering education with total obligations of $80 million. Many programs were targeted at specific, limited problems without a clear connection to a larger conception of the nature and needs of science education.

It is clear that the consensus existing in the 1950's and 1960's on the nature of these needs and on the strategies to be provided had dissolved by the end of the 1970's. Most people agree today that there are problems with the state of precollege training in science and mathematics. What they are less able to agree upon, however, is the exact nature and causes of these problems and the appropriate roles of various levels of government and the private sector in addressing them.

It was for this reason that the National Science Board established a Commission on Precollege Education in Mathematics, Science and Technology in April 1982. You have heard Mr. Coleman and Dr. Branscomb describe the activities of the Commission. We at NSF anticipate that the Commission's report will help provide a broad foundation for building a consensus for the 1980's and 1990's.

NSF will always have a limited but critically important role in precollege education within its basic charter and responsibility for the health of science. In fulfilling these responsibilities, it is incumbent upon the Foundation to select and design its activities in such a way as to exert high leverage, demonstrate leadership in the national interest through example setting and prototype testing, involve research scientists and engineers in educational concerns, be as flexible as possible and receptive to new ideas, and promote the involvement of State and local governments and the private sector in its undertakings.

The Foundation's fiscal year 1984 budget request continues two Presidential initiatives developed in fiscal year 1983 which meet the above criteria. These initiatives are still awaiting congressional approval. They are aimed at raising the stature of science and mathematics teachers at the secondary level and at improving the knowledge and skills of teachers of mathematics and science in grades 6 through 12.

The Presidential awards for teaching excellence in science and mathematics program identifies outstanding secondary schoolteachers of these subjects and recognizes their achievements and contributions in developing the Nation's future scientists and engineers. The fiscal year 1984 request maintains this program at the fiscal year 1983 level, providing support for 100 awards to teachers selected nationally from each State and other jurisdictions.

Support for the second of these initiatives, the presidential secondary school science and mathematics teaching improvement program, is increased in fiscal year 1984. This program supports workshops and training activities to improve the subject matter knowledge of science and mathematics for teachers in grades 6 through 12. It is estimated that by fiscal year 1984, it will have reached some 11,500 teachers.

These two programs are part of the administration's effort, working through the NSF and the Department of Education, to increase the numbers of qualified secondary school science and mathematics teachers.

The administration and NSF are anxious to join the Congress in improving the State of precollege science and mathematics education, but it is essential that a consensus be developed on the approach to be taken. It is also essential that the approach be built on a strong foundation which is deliberately focused and looks to the future. This goal cannot be accomplished overnight.

Another critical part of the educational base which provides the Nation's engineers and scientists is the small predominantly undergraduate college. A significant proportion of students awarded the Ph. D. in science, mathematics, and engineering receive their baccalaureates at these institutions. In the period 1967-1976, for example, more than 9,500 Ph. D. recipients in chemistry had their baccalaureates from 198 predominantly undergraduate colleges.

In fiscal year 1982, 20 percent of the NSF graduate research fellowships went to graduates of such colleges. These colleges serve as an important pipeline for entry into the system of graduate education, and finally, into the scientific and technical enterprise of the country. It is important that faculty in these institutions receive support and encouragement for maintaining their research capability.

The fiscal year 1984 budget request builds on and refocuses earlier NSF research efforts at the undergraduate level by proposing a new program, undergraduate college research support, to be supported at the level of $3.0 million. It will be budgeted for and managed in all of NSF's major research activities. This will insure the work it supports is adequately coordinated with other NSF-supported research and facilities at the Nation's leading research institutions. This is part of my larger management plan for fiscal year 1984 to bring programs such as these into the mainstream of the Foundation's activities. I shall be describing this plan in more detail in later hearings before this committee.

This new undergraduate program will emphasize independent research by faculty at predominantly undergraduate colleges, using the physical resources of major university, industrial, or Government research centers, and it will encourage the inclusion of advanced undergraduate students as part of the research team.

Funds for essential permanent equipment will also be provided. This program will help improve the quality of the research environment at small institutions which serve as major sources of future scientists, engineers, and technicians. We will be working with representatives of these institutions to further develop the program.

The historically black institutions have played a key role in the education of minorities in this country. Thus it is important that they, as well as other predominantly minority institutions, have strong scientific and engineering research capabilities.

The fiscal year 1983 budget will continue support of the research improvement in minority institutions program established in fiscal year 1982, in response to Executive Order 12320, to help predominantly minority colleges and universities with graduate science or engineering programs to improve their research capabilities. Thirty institutions are eligible to compete in this program. Four received awards in 1982, and an additional eight awards are anticipated in 1983.

The minority research initiation program provides support for full-time minority faculty, who have received no previous Federal research support, to establish research programs on their campuses. In fiscal year 1983, 20 awards totaling $2.0 million are planned. This level of support is continued in the fiscal year 1984 request.

In another effort to encourage the full use of the Nation's scientific and technical resources, the Foundation established the visiting professorships for women program in 1982 and made 17 awards last year. These visiting professors, in addition to teaching and research, are available to offer advice and provide mentorship at all levels from undergraduate to faculty. Twenty-five awards are planned in fiscal year 1983 at an expenditure of $1.5 million. This level is continued in the fiscal year 1984 request.

Shortages of young faculty in colleges and universities, particularly in engineering and computer sciences, is of great concern. NSF has included in its 1984 request a Presidential young investigator award program to respond to this need. NSF plans to make about 200 awards annually. Each award will provide up to 5 years' support at an average of $30,000 per year per award. This amount will be matched by a like amount of money from industry.

Participation in faculty research projects as a research assistant is the traditional manner through which graduate students gain practical research experience. This apprenticeship system of graduate education is the main reason that NSF awards go primarily to researchers at universities and colleges. In the fiscal year 1984 budget request, there will be an 8.4-percent increase in the number of graduate students receiving such support under NSF grants, bringing the total to an estimated 10,400. More than $92 million will be used for this purpose, an increase of 16.2 percent over the previous year.

In addition to research awards, the Foundation's graduate research fellowship program will support about 1,390 graduate fellows in fiscal year 1984 at an increased stipend of $8,100 per year, plus a cost-of-education allowance. Included in this total are 45 new and 135 continuing minority graduate fellowships. These traditional, prestigious awards provide 3 years of support during a 5-year period and allow the student to attend the graduate program of his or her choice.

In the transition from student to scientist, the postdoctoral experience traditionally has served to top off formal education and immerse the new Ph. D. in full-time research. This process provides training to young investigators in invaluable research skills while offering a source of qualified research associates for senior scientists.

Postdoctoral opportunities vary substantially from field to field, depending on the state of the industrial and academic job market. In the Foundation's fiscal year 1984 budget request, it is estimated that NSF awards will provide support for 3,189 postdoctoral scientists at a total cost of $54.9 million.

This is an increase of 87 percent in the number supported and an increase of 18 percent in the resources devoted to this important segment of the educational base for science and engineering. Particular emphasis is placed on the expansion of support for postdoctoral positions in plant biology and mathematics. This emphasis is in keeping with the Foundation's thrust in these two areas in fiscal year 1984.

In conclusion, I believe it is important that we keep in mind the total system of education and training in this country for producing future research scientists, engineers, and technicians, and for producing a technologically literate public.

This system consists of a continuum extending from primary and secondary schools through graduate school and the postdoctorate. I believe that our fiscal year 1984 request addresses the needs of each part of this continuum, with a special, and appropriate, focus on graduate education.

In some sense nearly all of the Foundation's budget is devoted to science and engineering education. I hope that I have been able to convey this in my remarks. The revitalization of our universities as exciting places at which to conduct research and to train new generations of scientists and engineers is an important challenge for this Nation.

Thank you, Mr. Chairman. I would be pleased to respond to any questions you may have.

[The prepared statement of Dr. Knapp follows:]

STATEMENT OF DR. EDWARD A. KNAPP

Mr. Chairman and members of the committee I am pleased to be here for your first day of Hearings on the Administration's fiscal year 1984 budget request for the Foundation.

Today's hearings focus on science and engineering education and training, a subject of great current interest and concern in the Nation, the Congress, and the administration especially as it bears upon the quality of pre-college education today in our secondary schools. We at the Foundation share this concern and are moving in a concerted and deliberate way to develop a clear consensus on the nature of the problem and the strategies needed to alleviate it.

At this point I would like to turn to Dr. Lewis M. Branscomb, Chairman of the National Science Board, for some comments on the role the Board has played in setting the overall budget strategy for fiscal year 1984 as well as its role in developing this consensus for the Foundation's role in science and engineering education.

The educational base for producing the Nation's future research scientists, engineers, and technicians consists of a continuum extending from primary and secondary schools through undergraduate colleges and universities to graduate and professional schools and on to the post-doctorate appointment. As student move through these institutions, they make choices which are influenced very much by the quality of the faculty and teaching which they encounter and, at later stages, by the opportunities they have to gain first hand knowledge of the research process. In a real sense it can be argued that the entire budget of the Foundation serves to promote and strengthen science and engineering education.

I will describe in some detail how the Foundation's fiscal year 1984 Budget Request addresses this educational base. NSF's major responsibilities lie in graduate education and training in research which it supports through fellowships, stipends in research awards for graduate research assistants, and post-doctorate awards. This reflects the broad consensus which has developed in this country since the 1950's on the role which the Federal government plays in the support of long-term, fundamental research and in maintaining the health of the basic research enterprise. The training of graduate students through an apprenticeship system of working with university faculty who are themselves successful researchers is an absolutely critical part of this enterprise. NSF also has a role, but necessarily a more selective one, in the area of precollege education.

Pre-college education in the United States in a vast, decentralized enterprise with some 16,500 local school districts. Since the beginning of our Republic, it has been and remains a major responsibility of states and localities reflecting the deeply held belief that education should be responsive to the needs and views of the local community and the family.

There has also been a considerable degree of Federal interest in pre-college education since our first days as a Republic because of the belief that a well-educated citizenry is the backbone of a democracy. To that concern we would add, today, the belief that a competitive, strong economy and secure society depend on the quality of scientists, engineers, and technically trained personnel. It is also true, however, that there has been much less consensus on the appropriate Federal role in pre-college education, including pre-college education in science and mathematics, than on the role of local communities.

As the members of this Committee are well aware, the Foundation has operated a broad range of science education programs for many years. We concentrated on science curriculum development, on teacher training, and on the development of scientific manpower. There was general agreement at that time that this was an appropriate role for the Federal government and the Foundation to play.

The potential for overlap between the then Office of Education and the NSF at the pre-college level, was resolved by "splitting the field": NSF would focus on science and operate mainly through the scientific community and through universities and colleges, the primary group with which it had constant interaction and who was the source of the most current scientific knowledge. This was, after all, its comparative advantage, given its responsibilities for basic research. The Office of Education, in turn, would work mainly through state and local education systems and focus on the broad application of education.

Though the dollar magnitude of the Office of Education programs—not to mention expenditures by states and localities—far outstripped those available to the NSF, there was widespread agreement that NSF's activities were, overall, well-targeted, well-managed and effective in meeting their objectives. For relatively small amounts of money, we were able to have a substantial impact on pre-college science education across the Nation.

In the 1970's, however, there was a reorientation of science education programs. Scientific personnel shortages were seen to be less acute and emphasis shifted to increasing the science literacy of all citizens and increasing training opportunities for groups with low participation in scientific and technical careers. By 1979, there were 28 different programs in science and engineering education with total obligations of $80.0 million. Many were targeted at specific, limited problems without any very clear connection to a larger conception of the overall nature and needs of science education.

It is clear that the consensus which existed in the 1950's and 1960's on the nature of these needs and on the strategies to be provided had dissolved by the end of the 1970's. Most people agree that there are problems with the state of pre-college training in science and mathematics today. What they are less able to agree upon, however, is the exact nature and causes of these problems and the appropriate roles of various levels of government and the private sector, in addressing them.

It was for this reason that the National Science Board established a Commission on Precollege Education in Mathematics, Science and Technology in April, 1982. You have heard Mr. Coleman and Dr. Branscomb describe the activities of the Commission, which are on schedule, and we at NSF anticipate that the Commission's report will help provide a broad foundation for building a consensus for the 1980's and 90's.

NSF will always have a limited, but critically important role, in precollege education within its basic charter and overall responsibility for the health of science. In fulfilling these responsibilities, it is incumbent upon the Foundation to select and design its activities in such a way as to: exert high leverage; demonstrate leadership in the National interest through example setting, and prototype testing; involve research scientists and engineers in educational concerns; be as flexible as possible and receptive to new ideas; and to promote the involvement of state and local governments, and the private sector, in its undertakings.

The Foundation's fiscal year 1984 Budget Request continues two Presidential initiatives developed in fiscal year 1983 which meet the above criteria. These initiatives are still awaiting final congressional approval. They are aimed at raising the stature of science and mathematics teachers at the secondary level and improving the knowledge and skills for teachers of mathematics and science in grades 6 through 12. The Presidential Awards for Teaching Excellence in Science and Mathematics program identifies outstanding secondary school teachers of these subjects and recognizes their achievements and contributions in developing the Nation's future scientists and engineers. The fiscal year 1984 Request maintains this program at the fiscal year 1983 level, providing support for 100 Awards to teachers selected nationally from each state and other jurisdictions.

Support for the second of these initiatives, the Presidential Secondary School Science and Mathematics Teaching Improvement program, is increased in fiscal year 1984. This program supports workshops and training activities to improve the subject matter knowledge of science and mathematics for teachers in grades 6 through 12. It is estimated that by fiscal year 1984, it will have reached some 11,500 teachers.

These two programs are part of the Administration's overall effort, working through the NSF and the Department of Education, to increase the numbers of qualified secondary school science and mathematics teachers.

The Administration and NSF are anxious to join the Congress in improving the state of precollege science and mathematics education but it is essential that a consensus be developed on the approach to be taken. It is also essential that the approach be built on a strong foundation which is deliberately focused and looks beyond the present to the future. This can not be accomplished overnight.

The small, predominatly undergraduate college is another critical part of the educational base which provides the Nations's future engineers and scientists. A significant proportion of those awarded the Ph. D. in science, mathematics and engineering receive their baccalaureate at these institutions. For the period between 1967-1976, for example, more than 9,500 Ph.D. recipients in chemistry had their baccalaureates from 198 predominantly undergraduate colleges. In fiscal year 1982, 20 percent of the NSF Graduate Research Fellowships went to graduates of such colleges. Since these colleges serve as such as important pipeline for entry into the system of graduate education, and finally, into the overall scientific and technical enterprise of the country, it is important that faculty in these institutions receive support and encouragement for maintaining their research capability.

The fiscal year 1984 Budget Request builds on and refocuses earlier NSF research efforts at the undergraduate level by proposing a new program, Undergraduate College Research Support, to be supported at the level of $3.0 million. It will be managed and budgeted for in all of our major research activities to insure that the work it supports is adequately coordinated with other NSF-supported research and facilities at the Nation's leading research institutions. This is part of my larger management plan for fiscal year 1984 to bring programs such as these into the mainstream of the Foundation's activities. I shall be describing this plan in more detail in later hearings before this Committee.

This new program will emphasize independent research by faculty at predominantly undergraduate colleges, using the physical resources of major university, industrial or government research centers, and will encourage the inclusion of advance undergraduate students as part of the research team. Funds for essential permanent equipment will also be provided. This program will help improve the quality of the research environment at small institutions which serve as major sources of future scientists, engineers and technicians.

The historically Black institutions have played a key role in the education of minorities in this country. Thus it is important that they, as well as other predominantly minority institutions, have strong scientific and engineering research capabilities.

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The fiscal year 1984 Budget Request will continue support of the Research Improvement in Minority Institutions program established in fiscal year 1982 in partial response to Executive Order 12320, to help predominantly minority colleges and universities with graduate science of engineering programs to improve their research capabilities. Thirty institutions are eligible to compete in this program. Four received awards in fiscal year 1982 and an additional eight awards are anticipated in fiscal year 1983.

The Minority Research Initiation Program provides support for full-time minority faculty who have received no previous Federal research support to establish research programs on their campuses. In fiscal year 1983, 26 awards totalling $2.0 million are planned. This level of support is continued in the fiscal 1984 request.

In another effort to encourage the full use of the Nation's scientific and technical resources, the Foundation established the Visiting Professorships for Women program in fiscal year 1982 with 17 awardees last year. These visiting professors, in addition to teaching and research are available to offer advice and provide mentorship at all levels from undergraduate to faculty. Twenty-five awards are planned in fiscal year 1983 at an expenditure of $1.5 million. This level is continued in the fiscal year 1984 request.

Shortages of young faculty in our colleges and universities particularly in engineering and computer sciences, is of great concern. We have included in our fiscal year 1984 request a Presidential Young Investigator Award program to respond to this growing need. Our plan is to make about 200 awards annually. Each will provide up to 5 years support. At an average of $30,000 per year per award. This amount will be matched by a like amount from industry.

Participation in faculty research projects as a research assistant is the traditional manner through which graduate students gain practical research experience. This apprenticeship system of graduate education is the main reason NSF awards go primarily to researchers at universities and colleges. In the fiscal year 1984 Budget Request, there will be an 8.4 percent increase in the number of graduate students receiving such support under NSF grants, bringing the total to an estimated 10,400. Over $92 million will be used for this purpose, an increase of 16.2 percent over the previous year.

In addition to research awards, the Foundation's Graduate Research Fellowship Progam will support approximately 1,390 graduate fellows in fiscal year 1984 at an increased stipend of $8,100 per year plus a cost-of-education allowance of $4,900. Included in this total are 45 new and 135 continuing Minority Graduate Fellowships. These traditional, prestigious awards provide three years of support over a five year period and allow the student to attend the graduate program of his or her choice.

In the transition from student to scientist, the post-doctoral experience traditionally has served to top off formal education and immerse the new Ph.D. in full-time research. This process provides training to young investigators in valuable research skills while offering a source of qualified and affordable research associates for senior scientists.

Postdoctoral opportunities vary substantially from field to field, depending very much on the state of the industrial and academic job market. In the Foundation's fiscal year 1984 Budget Request, it is estimated that NSF awards will provide support for 3,189 post doctoral scientists at a total cost of $54.9 million. This is an increase of 8 percent in the number supported and an increase of 18 percent in the resources going to this important segment of the educational base for science and engineering. Particular emphasis is placed on the expansion of support for post-doctoral positions in plant biology and mathematics in keeping with the Foundation's overall emphasis on these two areas in fiscal year 1984.

In conclusion, I believe it is important that we keep in mind the total system of education and training in this country for producing our future research scientists, engineers, and technicians.

This system consists of a continuum extending from primary and secondary schools through graduate school and the post-doctorate. I believe that our fiscal year 1984 request addresses the needs of each part of this continuum, with a special, and appropriate, focus on graduate education.

In some sense nearly all of the Foundation's budget is devoted to science and engineering education. I hope that I have been able to convey this in my remarks. The revitalization of our universities as exciting places at which to conduct research and to train new generations of scientists and engineers is an important challenge for this Nation.

Thank you, Mr. Chairman. I would be pleased to respond to any questions you may have.

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Mr. **Walgren**. Thank you, Dr. Knapp. We appreciate that presentation.

Let me ask at the outset if you would discuss with us the reservations expressed by Senator Garn to NSF in his letter regarding precollege activities in fiscal year 1983 in which the Senate, as I understand, took the position that the program submitted by NSF was not acceptable.

How are you going to respond to that?

Dr. **Knapp**. We will, of course, work with Senator Garn and his staff to understand his concern with NSF's program. We will try to develop a modified program, or perhaps a better explanation of the program, so that he can be satisfied with the program and its aims.

A little bit of misunderstanding is involved. However, I am not alarmed, nor even particularly surprised, that Senator Garn is not in full agreement. Within the community and within the Congress there is certainly less than complete unanimity on the correct approach to the precollege education crisis.

Senator Garn's letter included a large number of items which he felt that we had not considered for the NSF program. And in fact most of the items listed in his letter are efforts that NSF had worked on sucessfully in the past.

Many of those items are desirable for NSF programs in an era of greater resources. However, we produced a focused program in the area where NSF had good success in the past, namely, teacher institutes for training teachers and bringing them up to date in their fields. We felt it was important to avoid a program split into many segments at the funding available to NSF in the fiscal year 1983 budget.

I believe the program was well focused, and we will be meeting with Senator Garn in the near furture to explain why.

Mr. **Walgren**. Thank you.

Dr. **Branscomb**. Mr. Walgren, may I comment?

Mr. **Walgren**. Certainly.

Dr. **Branscomb**. One other aspect of his letter deserves comment because it implies that he feels NSF may not understand properly the distinction between the role that NSF can do well versus the role that the Department of Education can do well. I do think there is some misunderstanding, because his characterization of the strength of the Foundation is quite accurate and in agreement with NSF's view.

NSF is an innovative agency. It has deep connections with the science and engineering communities. It can rally them to these kinds of efforts. And it is appropriate that NSF has flexible innovative programs. I was a little startled that his letter didn't recognize that NSF is proposing a flexible innovative program; at least that is the way the Board feels about it. And I think he is under some, perhaps, misconception that there is confusion between the NSF and the Department of Education about their relative roles.

My impression is that there is little such confusion, and that the two agencies are quite different in their capabilities and in their orientations. As an outsider who doesn't spend much time in Washington, I would say that NSF and the Department of Education are working well together, and the issue really is not a major issue.

Mr. **Walgren**. This committee last week marked up another initiative in the education area in which we provided a $100 million matching fund, or a fund that would require matching to be implemented. Your 1983 fiscal budget, as I understand it, in the precollege area does require a match, a 100-percent match.

Dr. **Knapp**. That is correct.

Mr. **Walgren**. My question is whether, if we are successful in developing this new initiative in matching funds in this separate vehicle, whether that would allow the National Science Foundation to propose a program that might not require that same degree of matching in its precollege program.

Dr. **Knapp**. We have not seen the bill you have just marked up. You said the $100 million would require matching funds as is set forth in the bill, and would it be NSF's desire that it not require matching funds?

Mr. **Walgren**. No. It has been said that the proposal by the NSF to require a 100-percent match in their precollege education effort may rule out doing a number of things that perhaps we should do. It is somewhat inflexible.The question is, if we are now going to be providing a separate fund of really $150 million, $15 million of it which would be in the precollege area, that would require a match—would you anticipate broadening your precollege program at least in the sense of engaging in some activities that would not require the match that you are now proposing?

Dr. **Knapp**. I am still not sure I am going to be answering the question correctly. As for the program that the Foundation would work with the Congress to develop, if the Congress comes forward with a program with additional funds and strengths, there are activities the Foundation would propose to engage in which might be difficult to operate where matching was required.

As the broad bipartisan consensus develops for precollege education over the next few months, we would like to indicate NSF's role in precollege education and the kind of programs desirable for NSF to undertake.

Mr. **Walgren**. Continuing with the question I raised with Mr. Coleman about the loss in stopping cold some education functions in which there may be very broad agreement on their continuing, and thinking in particular of the public communications activities of the National Science Foundation as represented by the television program "3, 2, 1, Contact," and the like, is there any flexibility you can find within the agency to review those programs that were terminated and perhaps maintain some effort in those that have broad agreement as to their legitimacy and which we feel we will be going right back to as the Commission reports?

Dr. **Knapp**. We are reviewing that program within the Foundation now, and determining what NSF's role could be with the funding and guidance provided by the Congress for fiscal year 1983.

Mr. **Walgren**. We would appreciate being kept informed of that review.

Mr. **Brown**. Gentlemen, you know, I am not particularly prone to partisan sniping at your activities over there. But I can be swayed on occasion.

Mr. Branscomb, you are not testifying that there has been no real change in policy in this administration since 1981, which I recall very well you are appearing before this subcommittee about this time, in which we eliminated the support for instrumentation, we almost eliminated the education.

We eliminated most of the funding for social science and for international science. I seem to feel that what you are saying is we really just killed those off so that we could do them better, and we really supported them all the time. Is that what you mean to say at this point?

Dr. **Branscomb**. Mr. Brown, I believe "constructive tension" was your phrase. None of us is the only actor in this arena, as is fortunate since it is a democracy. The President, the Board, the Foundation, the Congress, and the people all have their opinions about what ought to be done. When the administration made a set of decisions in March 1981 which was reflected in the budget you described, the Board issued a statement. That statement addressed the issues you describe.

Now, it may be that that statement was not written in sufficiently boldface letters for the Congress. But I assure you, my friends in OMB understood what the Board was trying to say, and there was some "constructive tension." The Board at that time said, "the Board can see a crisis coming of serious proportions in precollege mathematics and science education. While agreeing that public schools are primarily local responsibility the Board "is convinced the Foundation has an indispensable catalytic role it should not abrogate even if the level of investment is severely curtailed."

The Board proceeded in August of that year to issue a policy statement on science education in which it identified two major priorities. The first, unique responsibilities of the Foundation for research-level education; by that I mean colleges and universities. This priority involves the evaluation and monitoring of a national science and engineering education system with respect to human resources to meet national needs.

The Board's second priority was leadership in identifying areas of special concern. It involves encouraging other agencies, State and local governments, and private organizations to meet the needs and for NSF to "intervene in selected areas where significant improvement in educational outcomes is possible within limited investment." Limited has to be understood in the context of a kindergarten through grade 12 expenditure in this country of $100 billion.

Now, on the same day, the Director's implementation statement was presented to the Board and approved by the Board. The Board said, "OK, we are going to implement your policies." The priority for exercising leadership to encourage private and other governmental units to meet the needs was going to be done through the Commission; and there were several specifics.

The specifics were materials for science teachers to convey new knowledge and technology; interaction among science teachers, colleges, universities and industry and regional resource centers for needs assessment; in-service training; encouragement of science interest among minorities and women, and local leadership development.

In the same meeting the Board approved a budget request of $50 million for the fiscal year 1983 budget. So I do not sit here to tell you that the Board made a decision to back away from all these programs in order to wait for the Commission to do its work. On the other hand, I do not come here today to excoriate the administration. I think the administration inherited a politically unviable situation in science education. This committee has been long involved in that history. This committee has fought for it consistently over the years.

But between the committee and the administration, both political parties, the public and NSF, that effort dwindled from the early 1970's. While Mr. Reagan may get credit for the ultimate dwindling, the effort had pretty well dwindled by the time he got it. It was fragmented in 27 pieces. The rebuilding is urgent but—excuse me.

Mr. **Brown**. You would make similar statements about the cut in the—the $75 million cut in instrumentation and the other cuts that I have referred to?

Dr. **Branscomb**. The instrumentation cut is a little different. The Carter administration proposed a major initiative in instrumentation, which the Board strongly supported as part of a major increase in the last Carter budget. The new administration had to confront a budgetary rescission.

It was not incumbent upon them necessarily to defend to Congress their predecessor's budget.

Mr. **Brown**. Yes.

Dr. **Branscomb**. I regret the fact that 2 years have passed without the opportunity to address that issue. I am pleased that we are now addressing it. The constructive tension with the administration has produced some good results.

Mr. **Brown**. I think you have put this all in a good flight. I, of course, continue to have high regard to your own perspicacity and understanding of these issues. I very much welcome the status we are in today where we are now reasserting the high importance of these programs, whether we redefine them in some cosmetic way or not, the programs themselves are important.

I don't think this committee ever tried to mandate on NSF or the Board exactly how we would fulfill these important national needs. But we recognize that they existed and needed to be filled. I think this program goes a long way in fulfilling them. I commend you and Dr. Knapp for succeeding in utilizing that constructive tension for this worthwhile result.

Let me just deal with one additional question which is high on my personal agenda. In your statement on page 5 you say that the Board sees striking reasons to invest in research in computer science, electrical, and computer engineering and application of new information technologies, and in addressing the most urgent problems in education in computer skills. You wouldn't go so far as to endorse my legislation to set up a Policy Institute for giving us some national direction in that field, would you?

Dr. **Branscomb**. I must confess, Mr. Brown, I am not so familiar with it as I should be. I will make myself familiar with it.

Mr. **Brown**. Yes. How would you feel about making this the subject in, say, the next 6 months or a year, after the present Commission expires, of another outstanding national level commission to try and address this complex of important problems as a coherent issue?

Dr. **Branscomb**. It is well worth considering because there are many facets of information technology phenomena, if I can call them that, which are new and uncharacteristic of our previous history, and about which there is both poor understanding and poor unanimity. The disciplinary structure of that field is fragmented and dynamic. That is part of its strength, but part of the confusion.

The Board, in fact, will be debating this next month and again in May the internal organization and priorities of the Foundation in information science, computer engineering, computer science.

There also is a tremendous enthusiasm for the role of computers in education. It is quite remarkable in the view of the disappointed persons in the 1950's and 1960's when that same enthusiasm played out to no effect.

Mr. **Brown**. Yes.

Dr. **Branscomb**. But we have seen the enthusiasm in the projects that NSF has supported particularly in Rochester, Minn. where this year 6,000 school kids will be trained on personal computers. It is extraordinary, the positive effect it has on both teachers and students.

Let me say we have some great opportunities in engineering education built around the computer technology to improve the productivity of industry. We need young engineers who see production technology as a challenging career in development. That is also being driven by computer technology.

Mr. **Brown**. Did you have a chance to meet with any of that Swedish delegation I referred to earlier?

Dr. **Branscomb**. No, sir, I didn't.

Mr. **Brown**. They are a parliamentary commission on what they call "inframatics," which is a term the French use, also. It includes the whole scope of what you referred to here. Our friends in Japan have similar institutional mechanisms for reviewing this field. My legislation was an attempt to match this effort in some fashion.

But of course, no particular institutional arrangement has any magic. I would very much appreciate it if the Board would at least give some thought to the possibility of recommending to the President a commission in this area. It is the simplest approach, one which is already embodied in law and has been for many years. It would provide an opportunity to bring together, as the science and math education group has, outstanding group of leaders in the country to focus on this in a homogeneous way.

Dr. **Branscomb**. The Board will certainly discuss it. We will inform ourselves about the developments in the Commerce Department which suggest to me that the governmental capability for dealing with those issues is diminishing rather than growing.

Mr. **Brown**. Well, in discussing this myself with the Swedes I pointed out what they were familiar with, a huge proliferation of activity here, but no one comprehensive way of analyzing this in terms of what it is doing to the future of this country or the quality of living in this country, or any other similar national goal. I think that is where we have a lack at the present time.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Brown.

Mr. Bateman.

Mr. **Bateman**. Thank you, Mr. Chairman.

Mention has been made of Senator Garn's letter of February 17. I have now had an opportunity to see and read a copy of it. Had the letter been addressed to me, I think I would have had to have sent back a response to the effect: "Your message was received, would you please send a translation?"

I have read it, but I am not at all sure I can focus on the concerns. There is, of course, a concern on my part, and I think Dr. Knapp and Dr. Branscomb have already indicated they haven't had a chance to look at in the marked up bill that the committee has sent forth any detail.

I think I would be benefited, and perhaps all of the committee, to have your observations on what the legislative process to this point has brought forth, and whether or not you see points of sensitivity in terms of what the bill in fact provides insofar as the operative relationship between the National Science Foundation and the Department of Education.

There is a certain degree of nervousness on my part as to whether or not we have done our job as well as would have been desirable in a perfect world of spelling out the operative relationships between the two and whether or not you, as well as I, would like to know the views of the Department of Education as to whether you feel a need for further clarification or definition of roles.

I appreciate your testimony.

Mr. Chairman, I don't have any compelling questions that come to my mind. I simply offer those comments.

Dr. **Knapp**. I would like to comment on those points. In considering agency roles, it is important to have activities as compatible as possible with the agency's customs and practices and to capitalize on the agency's strengths. For NSF, that means we talk about open competition, emphasis on excellence, use of peer review. The latter not only gives NSF rigorous quality control but also makes NSF more receptive to new ideas, from the field.

The open window feature I just spoke of is one of NSF's traditional strengths. Another is the professional scientific and engineering community in the United States to which we are tightly connected. NSF is highly respected by that community and knows how to deal with it. So we think NSF's role should be in activities that use competition, peer review, the scientific community of the United States, and part of the educational training community; working together as a team.

The Department of Education is strong in different areas. We have worked quite hard with the Congressmen who are drafting the legislation that you just marked up. NSF ideas are interwoven into what you are putting forward because there is a delineation in that bill between the role of the NSF and the role of the Department of Education. We are pleased with the results that we know of to date. I understand, however the bill is still being worked on and is still not reported to the full floor.

Dr. **Branscomb**. May I a comment?

Mr. **Bateman**. I would be happy to have it.

Dr. **Branscomb**. I am thoroughly in accord with Dr. Knapp's point on the importance of the Foundation undertaking those efforts for which it is best fitted. And I believe there may be efforts in H.R. 1310 that really will be done best if NSF undertakes them.

But with respect to title II, while the Board has no position on any part of the bill, I myself think the title is an effective way of approaching the issue because it is broad, it is congruent with NSF's enabling statute.

I want to comment on the chairman's comment about matching funds because I am not familiar with that element of title II. I feel comfortable about the matching idea in NSF's precollege science education initiative this year because, there is a lot of interest in the private sector at the moment in helping the schools, and the schools themselves, of course, have budgets, they are publicly funded institutions.

At the university level, when you think about matching, bear in mind the important role of the private colleges and universities. Be sure that their capability to match under the terms of the law are not at a disadvantage with respect to the ability of a State institution to match.

It really depends on whether matching is by faculty salaries in kind, so to speak, which all institutions equally provide, or whether there is a need to have State appropriations that would help a private institution to match. That may be difficult to expect from most States.

Mr. **Walgren**. Thank you.

Mr. Skeen.

Mr. **Skeen**. Thank you, Mr. Chairman.

Dr. Knapp, Dr. Branscomb, both of you made strong references to plant biology, a particular interest of mine and those of us who are involved in agriculture and interested as we deplete the fertility of the soil of this whole earth of ours. I never cease to be amazed at what new developments take place that once again reinforces the ability of this earth to support us. I think that you have made appearances before the Subcommittee on Natural Resources, Agricultural Research and Environment in which the statement was made by one or both of you that only 5 percent of the, or something like 5 percent of all plants that are edible have been developed for market use. I have some questions in connection with that.

Could you sketch out what is the potential at this point in plant biology and economic botany, the use of this area? I am extremely interested and I would appreciate it.

Dr. **Knapp**. I don't know about testimony to a natural resources committee.

Mr. **Skeen**. I think it was Dr. Branscomb.

Dr. **Branscomb**. No, sir, I don't think it was, it might have been a Board member.

Mr. **Skeen**. Oh, the Department of Agriculture.

Mr. **Brown**. You have a pair of physicists before you, sir. We have real experts in the Foundation that can answer your question right.

Mr. **Skeen**. I will take whatever you have got to offer.

Dr. **Knapp**. Within the past month, a spectacular advance in genetic engineering in plants has been recorded. It is associated with nitrogen fixation in plants. Nitrogen is a common element in the atmosphere, but plants can't use nitrogen as atmospheric nitrogen, they must use nitrogen as ammonia, which is fixed in nature through a symbiotic relationship between bacteria living in nodules in plant roots.

Just last month, through genetic engineering it was possible to get nodules to grow on a plant which normally does not fix nitrogen. This is the first major demonstration of genetic engineering in a plant system. It looks like it might lead toward substantial commercial application. It was extremely basic research, very much at the forefront, and partially supported by the National Science Foundation.

There are many other opportunities for advances in plant biology, some of them not in the fancy genetic engineering areas. For example, we haven't even cataloged all of the plants which grow on this earth, particularly in the tropics where there are gigantic forests with many species. It was only recently that a new species of corn was found in Mexico. It was then bred with other species of corn to make more disease resistant plants. Several areas of plant biology are ripe for further investigation.

Dr. BRANSCOMB. I would add only one thought. I am sure the excitement in this area will be conveyed through announcements like the ones Dr. Knapp, just made. Perhaps the characteristics of a plant can be altered with respect to its requirements for fertilizer, or needs for water, or vulnerability to pests. As the basic scientific tools of this discipline are improved, researchers' ability to measure and characterize the genetic nature of a given species is increased, we will find a productivity enhancement important to agriculture. Instead of experimental plant breeding in order to get genetic improvement, an old and powerful tool of agriculture, a researcher can sit down and theoretically predict which of 75,000 natural strains in the seed bag are the right 5 to breed together to get the desired characteristics.

If he ever gets it right, then he can change 10- or 15-year development cycles down to perhaps one or 2-years. The responsiveness of plant genetics to commercial and agricultural needs could be important.

Mr. SKEEN. How close are you with the AID program and the Department of Agriculture for development of this technology? Does the NSF work closely? I know you do with the Department of Education and so forth, but it is a curiosity with me because I think this is a major development.

Dr. BRANSCOMB. My personal relations are excellent because Nyle Brady is an old colleague. My company in fact provided free computers and other instruments in the Philippines to further this kind of work. I am sure the Foundation experts are close to the agricultural experts in AID, and I am sure NSF supports them technically in many of their activities.

Mr. SKEEN. Insofar as using more species of plants for economic purposes, do you envision the field as wide open in this area? It is to me.

Dr. BRANSCOMB. It is to me, too. I keep thinking natural material products may be an important beneficiary, too. People don't talk much about improving the structural characteristics of wood or natural fibers, but I suspect there are opportunities there as well as in food products of a more conventional kind.

Mr. **Skeen**. I appreciate the emphasis both of you have made in this area, and thank you both.

Dr. **Knapp**. I would like to make another comment. It has to do with the educational aspects of NSF's work we are discussing today. Plant biologists are, in short supply. One of the emphases we will be putting in NSF's graduate educational program is support for young people who would like to go into the field of plant sciences; in particular, those who have skills in genetic engineering.

Mr. **Skeen**. I am a little amazed that we have so few laboratories, at this point with the private sector people working in this area. Here is one of the good examples of a fairly new technological innovation that has tremendous economic impact and we are still not seeing a great deal of response.

Maybe it is early. I do appreciate the emphasis and appreciate the testimony today.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Skeen.

Mr. Mineta.

Mr. **Mineta**. Thank you, Mr. Chairman.

Dr. Knapp, and Dr. Branscomb, I am the new kid on the block here, and I appreciate your being here to help further enlighten me about issues that you are dealing with.

1982, the buzz word was "infrastructure". The buzz word in 1983 seems to be "high technology".

The thing that sort of bothers me about just a cursory glance at what we are doing is that it is a start and stop kind of a mechanism. Over the years, not with regard to any administration or any directors or any chairs of the National Science Board, but it seems like we go through the stop/start kind of thing.

I am wondering, is there a way to sort of lay out a 5-, 10-, 15-year picture, and in terms of needs and goals, how do we get there, in terms of basic or applied research?

It seems to me as we talk about infrastructure inroads or investments in capital expenditures, that somehow we ought to be doing the same kind of thing as it relates to investment in human capital and the field, basic fields of science and engineering.

I am wondering, has that ever been undertaken by the NSF so that it is not just surge of a sputnik or computer chips. I come from San Jose, Calif., which is the heart of Silicon Valley where we have got all of the semiconductor companies and all of this high technology going on. We are bothered by the fact that our labor force is not properly prepared for the kinds of jobs that are available. I sometimes wonder whether or not we really have an idea of where we are going.

I was just wondering if you might comment on that.

Dr. **Knapp**. I will comment, and I think Dr. Branscomb would like to comment, too.

Within the scientific disciplines supported by the National Science Foundation, there are well developed 10-year plans for what those fields would like to do in terms of growth, equipment, directions, and manpower.

Within the country's personnel pool for science and technology, I know of no long-range plan along such lines. It is difficult to plan because people trained in a scientific discipline, say, chemistry or physics or astronomy, many times work in fields different from those they trained in. But, it turns out that they are trained better for the job they take than if their training had been more focused. For example, the Bell Telephone Laboratories over the past 3 years have been developing a large, new switching system for transcontinental telephone systems. They have hired 15 percent of all Ph. D. physicists produced in this country each year for the past 3 years; 150 Ph. D.'s per year, and they are not doing physics research when they go to work for Bell Labs. Some are, but many are not. It happens in the graduate schools for physics research that these people learn while doing their research many aspects of systems development and computer data acquisition all directly necessary for the Bell Telephone Laboratories in the development of the switching system.

It is difficult to say Bell Labs will need in the next 10 years so many physicists or so many chemists or so many astronomers because these scientists work on different subjects than those in which they are trained. What they are trained in primarily is a way of thinking about a problem and a way of attacking a problem rather than in specific skills. That is to say, the scientists in these fields are broadly trained, and broadly trained people are needed in new developments at, I am sure, IBM and the Bell Laboratories.

So we can't just look at statistics and say the companies will need 5,000 new scientists of a certain category every year for the next 10 years in order to make up the pool needed for taking technology forward.

It is difficult to do. I would like to see a study of past experience so we might be able to extrapolate from it.

Mr. MINETA. But even if we can't quantify, we know that—the faster we run, the behinder we get.

Dr. KNAPP. I have a feeling that in 1970, when newspapers ran articles about Ph. D. scientists driving taxicabs, that we did not have a surplus of scientists in this country, we had a dislocation. A number of people had lost jobs in the aerospace industries and they were taking a little while to find other employment.

As we have seen in the Japanese economy, the U.S. economy could absorb many more scientists and technicians than are in it right now, many more engineers than we have available if they were available, and we would see no more unemployment in engineering if we had double the number of engineers in this country. Industry could use these people and use them wisely if they were trained.

Mr. MINETA. But as we try to encourage people to get into the scientific field, and as you say, it is difficult to project what our needs are going to be, what about just general proposition as to whether or not we are training people to pursue their education not for the industrial private sector, but what about those that are going to be preparing for an academic career?

It seems to me we are eating our own seed corn right now. I was talking to the head of the chemistry department at San Jose University. At the instructor level they are looking for Ph. D.'s to start at $21,600 a year. Now, a Ph. D. in chemistry is not going to be attracted to San Jose State for a salary of $21,600. If they are, it is a starting place, and with the companies in our area, they can go easily, without any question, I mean at $25,000 plus an employee stock option program and, boom, they are out the door.

It just seems to me somehow—somehow we ought to be dealing with this. I am not just sure how.

Dr. **Knapp**. The administration has an initiative to deal with that problem in the fiscal year 1984 budget. It is the young investigators program in which NSF will make to young faculty awards averaging $30,000 to $40,000 a year for 5 years.

That award is an award. It is not a grant to do particular research. It is an award based upon the investigator's record in achieving his or her position.

The investigator can use that award, part of it matched by industrial funds, to do research he or she would like to do. That makes a low salary at San Jose State a lot more attractive because the investigator is also free to do attractive and interesting research. Many people would be willing to take a smaller remuneration if they had the freedom to follow what they would like to do. I think that program is a wise program.

Mr. **Mineta**. In San Jose we have, as you well know, the General Products Division. Art Anderson there is always dying. I wonder how many qualified computer science engineers are available to be hired.

Dr. **Branscomb**. I don't have the number, but the field is very competitive.

Mr. **Mineta**. How many would you say you hire at IBM?

Dr. **Branscomb**. I don't know the number of engineers that we have at baccalaureate level, but we get what some others might say is more than our share of the Ph. D.'s and graduate students in this area.

We share the concern of the Foundation and others with the seed corn issue you describe. In the past 2 years our company has increased its activities with the universities to ameliorate that situation.

If I may respond to your question in a slightly different way, let me divide this problem in three pieces: the innovation problem, mostly a private sector issue, which involves tax policy and related matters; the graduate education and research issue, which involves skilled professionals and new knowledge; and the precollege education issue. Before we can have the broad vision of the sort you call for, we first must get people to recognize that these three sets of issues are very tightly intertwined over a long time constant. I think we now have that understanding. I have been impressed at what the Governors in particular have been doing as they have realized that this is a good issue for Governors.

Each of those sectors now has a pretty good grip on what they think their long-term strategic issues are. If you ask the colleges and universities your question, they can give you good answers.

If you ask industry, they will tell you what they see as the long-range requirements for competitiveness. If you go back to the schools, you get similar answers.

The problems lie at the interfaces between the sectors. There, the much more concerted thought you are calling for is required. Let me illustrate with just one example, a relatively new issue for

NSF. The Engineering Directorate has been discussing it with the Board, thinking about the future effort.

The issue involves magnetics technology. You may be aware that Santa Clara Valley could just as well be called Iron Oxide Valley because there is as much money derived from the manufacture of magnetic recording disk files in the valley as there is from silicon chips.

But nobody knows that because nobody writes about it. The chips are fashionable. The magnetic recording is not fashionable. Yet there is one university with four or five faculty members in magnetics; about four universities have about two. So Arthur Anderson, whom you mentioned, has been talking to companies and other universities about a private initiative to begin in a university in this field. That is something the Federal Government must know about, because once it starts, there inevitably will be interest in universities.

That is exactly the purpose the private sector would have in stimulating it. So here is a field in which a U.S. industry leads the world and is being challenged by competitors overseas who are investing substantial sums of money for research in their universities in this technology.

NSF came late to the example of magnetic technology; it could have been anticipated had there been a thorough job done by combination——

Mr. MINETA. That is my point. There must be other things like that that we just haven't identified.

Dr. BRANSCOMB. I think there are.

Mr. MINETA. Yet the need is there and we will be facing a crisis at some point. The question is how do we avoid that crisis right now, by sort of crystal-balling into the future, not in terms of opportunities, but just areas.

Dr. BRANSCOMB. It is too difficult to wrap all those issues into a single study and single vision. In a pluralistic society, as we are fond of saying, keeping the process open to reveal those issues is important.

There are many forums today in which private citizens and Government officials are getting together to develop some kind of long-range consensus. An interesting discussion at the Carnegie Corp. a few weeks ago involved a broad spectrum of people discussing education for an economic strategy.

The Brookings Institution, I notice, is also having a conference of the same caliber. Those groups are not going to tell us what to do. Those groups are going to tell us what we have all decided already. They are part of a consensus-forming process.

It is important for the Foundation and the Board to use their extensive roots into the scientific community to be alert for early signals of changes in opportunities arising from new intellectual activities, and to take a leadership role in trying to bring forth a dialog even if the actions needed are not actions required of the National Science Foundation.

That is something that Herbert Doan, who until last year was vice chairman of the National Science Board and former president of Dow Chemical Co., always advocated; agencies like NSF and the

Board should do a better job than they do in articulating these examples and bringing them forth.

The Board is trying to do.

Mr. **Mineta**. Dr. Branscomb, in last year's hearings I believe it was Dr. Keyworth who mentioned that basic research was very healthy. Yet this year we see an 18-percent increase in basic research. Is that at the expense of what we ought to be doing in applied research?

Dr. **Branscomb**. The Board, in struggling with the distinction between basic and applied research, concluded a couple of years ago that, as conventionally used, the distinction is often not helpful. The Board said, in effect, the criteria we want to use for determining the appropriate kind of research for Foundation support is this: it must be research of high quality, competitive, reviewed by peers, and investigator initiated. That fits NSF's appropriate role. And when NSF measures quality, it will use two yardsticks at the same time.

One yardstick is, the intrinsic merit of the science from an intellectual point of view. What is its propensity for changing ideas about the world in a fundamental way?

The second yardstick is the likelihood of the research having practical value either in the distant future, perhaps great value, but a long time off; or, in the near term, an almost immediate value.

NSF does not downgrade the research it would support because the research is useful. Having said that, I also must say a great deal of the Foundation-supported research is of great and immediate use.

Take for example, research in the materials sciences—ceramics, polymers, magnetic materials, and so forth—where good fundamental work can be done and quickly used in industry. Those areas do not get perhaps as broad funding as they would if the budget as a whole were more generous, but they are covered. And NSF has a good balance between the area of highest intrinsic value—perhaps cosmology or high energy physics would be an example—and those of great extrinsic value like materials engineering.

But, if by applied research you mean problem-solving research aimed at a practical goal which must survive an economic test, I don't think either the Government or the universities are good at that task. It should be left to the private sector. Instead, NSF should foster the relationship between the private sector and universities.

Mr. **Mineta**. Even in the private sector, if it is a low yield, high risk, the private sector wouldn't be doing that kind of applied research, so it measures it in an economic sense and it doesn't measure it in terms of the value that might be derived in a generic sense.

Dr. **Branscomb**. I don't believe that is so, at least in those companies large enough to afford research laboratories as distinct from development laboratories. I don't view my job as improving the quarterly profits of the IBM Co. In fact, my job is to make them worse, since my principal emphasis is to spend more of what would have been profits for long-range, strategic objectives.

Mr. **Mineta**. But your idea is vastly different from a lot of companies where once the growth receipts start dropping, they also reduce the amount of money in R&D, whereas they really ought to be able to try to keep a constant amount in research and development.

Dr. **Branscomb**. That is a mixed bag. One of my competitors, Digital Equipment, had a poor fourth quarter and increased its budget in research. That is not at all unusual.

Mr **Mineta**. That is the anecdote people can point to in terms of an exception. Generally, an executive officer of a company, once he or she sees these figures starting to drop, will then start redirecting the resources.

As an example, one you just mentioned, Dr. Knapp, about nitrogen nodules, I am just wondering to what extent do fertilizer companies get concerned about all of a sudden the redistribution, let's say, of nitrogen. I don't know. I just use that because you use that as an example of a big breakthrough.

Dr. **Knapp**. The research has not reached that point yet. It is just the start of a long train of applied research. Basic research must be done in order for us to understand these processes and be able to engineer plants. The fertilizer companies do not need to be worried yet.

On the other hand, if corporations in the agricultural business could look far enough ahead, they would realize that they should have research programs in these areas so at least they will be able to understand the ramifications for their companies. Some do. I don't know the field well.

Mr. **Mineta**. Will NSF support applied research in fiscal year 1984, and how much?

Dr. **Knapp**. As Dr. Branscomb said, NSF doesn't distinguish between basic and applied research. Of the proposals received from universities, a certain percentage, are for applied research projects. These applied research projects fare as well as the basic research projects in the peer review process.

NSF is not a mission agency in the sense that it has specific goals and it supports specific research to specific ends. However, much of the Engineering Directorate's funding supports what could be called applied research. The submicron facility at Cornell University does the most fundamental studies in how to make semiconductor devices, in a sense, it is applied research.

Mr. **Mineta**. My 5 minutes are about to be up.

The chairman has been very generous and I appreciate again your adding to my understanding of what we have to deal with here in the Science and Technology Committee. Thank you very much. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Mineta.

If I could just touch on a couple of things quickly. We have gone on and I don't want to unduly delay you, and we have further witnesses.

It is my undestanding that the Congress has approached the NSF budget with respect to applied versus basic research, and that at least in terms of our trying to understand what is happening to the taxpayers' money, we have made the distinction.

Dr. **Knapp**. Yes.

Mr. **Walgren**. If you take the position that you do not distinguish between applied and basic research, that may be a proper approach at this point. If it is, I would think that the Congress would deserve a very clear statement so that we can understand that these moneys are being spent in a way we approve of.

When you folded the international programs into the other directorates' efforts and when you move away from the women and minority programs, somehow or another you are going to have to replace those distinctions with something we can follow and track.

Dr. **Knapp**. We do so with applied research. We do not distinguish when we receive proposals and when we decide to fund them, but we carefully categorize the research that we do fund as to whether it is applied research or basic research. The definition used is the same across the entire Government to determine what is basic research and what is applied research.

We have detailed numbers on what fraction of NSF's budget in each directorate supports applied research and what fraction supports basic research. The Congress does get a reporting of exactly what is funded and what NSF is doing in these fields.

Dr. **Branscomb**. I should correct my earlier statement. I said we don't distinguish, but the Director is absolutely correct. NSF does distinguish and it measures and tracks and it can report. The important issue is that NSF doesn't make that distinction in evaluating the merit of proposals.

NSF manages it so that each discipline covers the full spectrum ranging from basic to applied research. But I would urge you to be realistic about the nature of that distinction. You will find most companies don't make that distinction in their corporate laboratories. That is because they think everything they fund is useful. They wouldn't fund it at all if they didn't think it was useful. They think some long-range, high-risk projects are useful because they have high potential payouts. Short-range projects of low risk and known payout are also useful. Therefore, at the margin of that definition between basic and applied research, you can't really expect much precision.

For example, earthquake engineering, earthquake hazard mitigation, is a splendid example of applied research. The benefit you are trying to achieve is clear, and a coordinated interdisciplinary program is set up to achieve an objective with a planned way do so. We do, of course, continue to support goal-oriented interdisciplinary work in the Foundation. It is all explicitly available to you for review.

Mr. **Walgren**. As I understood Mr. Mineta's interest, it was to identify the research as applied versus basic, and that you do have information to that effect.

Dr. **Knapp**. Yes.

Dr. **Branscomb**. But I would plead with you not to interpret our answer on basic research as of on interest to industry. And I would plead with you not to assume that applied research doesn't have fundamental intellectual value. As the Foundation is managed today, the answer to both questions is yes and sometimes.

Mr. **Walgren**. We certainly respect your ability to make the proper judgment of what the right research is to fund. What we require is a way to evaluate your judgment along that line. This applied, versus basic distinction, goes to that point.

Let me ask on social sciences, Dr. Branscomb, social and math, on page 4 of your testimony you note that mathematics, the field has been neglected for a number of years.

You make the same point with the social sciences. Could you describe the neglect of the social sciences over the last several years?

Dr. BRANSCOMB. Let me have a moment to find that particular remark in my testimony because it is carefully worded. I said the field of mathematics had been neglected. By that I meant that too many of us on the Board and elsewhere assumed that because mathematicians didn't use equipment—mathematicians, mostly think about pencils and paper—perhaps we should think of them a little more like historians in the sense that they can do their work without a great deal of Federal attention.

I think that judgment is wrong because we in effect underestimated the importance of research support as a means of attracting able young students and financing their graduate educations. So I feel the field of mathematics has been allowed to dwindle and shouldn't be. And so I said the vitality of the field has suffered and needs some rebuilding.

So, too, do selected areas in social sciences; they need rebuilding; it is the rebuilding I am speaking of.

Mr. WALGREN. Could you describe the rebuilding of social sciences need at this point?

Dr. BRANSCOMB. In the budget reduction of the previous year, a lot of excellent work had to be given up. The Board's view is that it shouldn't support research in every kind of social science or every project. But the Foundation has had, over the years, an important and constructive role in the development of the social sciences, most especially helping them to become more quantitative, more experimental, more verifiable, more predictive sciences.

To the extent NSF has been able to do so, that is of great value to the country, particularly as the social sciences increasingly contribute to productivity in the service sector. NSF gave special emphasis, let me say, to the preservation of the major data collections and their further evolution because those data collections play a critical role in the evolution of social sciences as experimental disciplines. Some of those investments had been reduced even though NSF kept them in a high priority; they needed some expansion.

Let me make one other comment. There are areas that are by convention called social science, psychology, for example. Some parts psychology have a direct and immediate bearing on important areas of industry. Take human factors of computer systems, for example. Eighty Ph. D. psychologists in my company work in that area, but there is no good methodology whereby the design of an easy-to-use computer program can be computed in advance. If anybody knew how to do that, it would have great economic benefits.

So there are fields of social science—I have picked only one example—that have practical value and relatively immediate payoff. They deserve as much priority, in my view, as the physical sciences.

Mr. **Walgren**. How are we to judge whether they are receiving the proper priority? From one view the social sciences took a much deeper cut than did the others, and then when time for restoration of strength comes back, they participate only on average, and even that is an average among disciplines, to the same degree as the others. We are faced, therefore, with a sharp diminution of comparative effort. Now, how can NSF and the Board assure the Congress, or prove to the Congress, not just assure—I think it must go beyond assurance—how can you demonstrate that the areas that, as you cite should have as much priority as the others, are in fact being given that recognition?

Dr. **Branscomb**. On the broad perspective of physical sciences versus social sciences, it is worth observing that the emphasis that the Board put on physical sciences and engineering, beginning back in 1980, was in part a consequence of observing that during the late 1970's social sciences research supported by the government as a whole grew substantially faster than did the physical sciences. At least the data I have seen suggests that is so. Now there is a high priority attached to the physical sciences. But you are correct about the severity of the retrenchment and the need to redress it.

I would make only one observation about the budget increases in the fiscal year 1984 budget. For most of the disciplines of an experimental character, NSF has put in large increases to provide the money for equipment.

The ratio of the equipment requirements in the social sciences to those in the physical sciences is lower. Dr. Knapp will have to give you specifics, but my impression is that the amount of incremental research effort that a given percentage increase in the budget can buy in fiscal year 1984 in the social sciences is probably greater than in the physical sciences and engineering where a significant part of that growth must be reserved for equipment.

Mr. **Walgren**. If I could, could we ask somebody in your organization, Dr. Knapp, to make exactly that analysis?

Dr. **Knapp**. Yes. We will supply it.

Mr. **Walgren**. Particularly with respect to past budget years, perhaps pick the last year. Let's see just what exactly the instrumentational needs of, let's say, the math and the physical sciences were, and those that were addressed by the Foundation, versus the noninstrumentation needs so that we can compare the actual underlying intellectual effort made in both those areas.

Could we do that?

Dr. **Knapp**. Yes.

[The information follows:]

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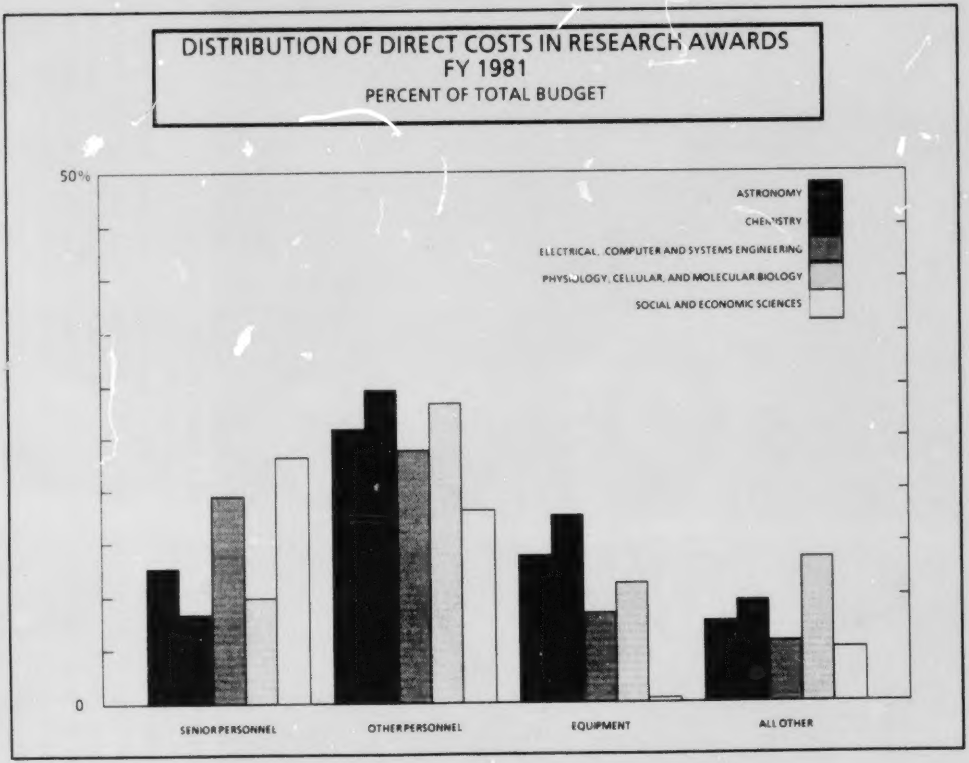
DISTRIBUTION OF DIRECT COSTS IN RESEARCH AWARDS
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DISTRIBUTION OF DIRECT COSTS IN RESEARCH AWARDS
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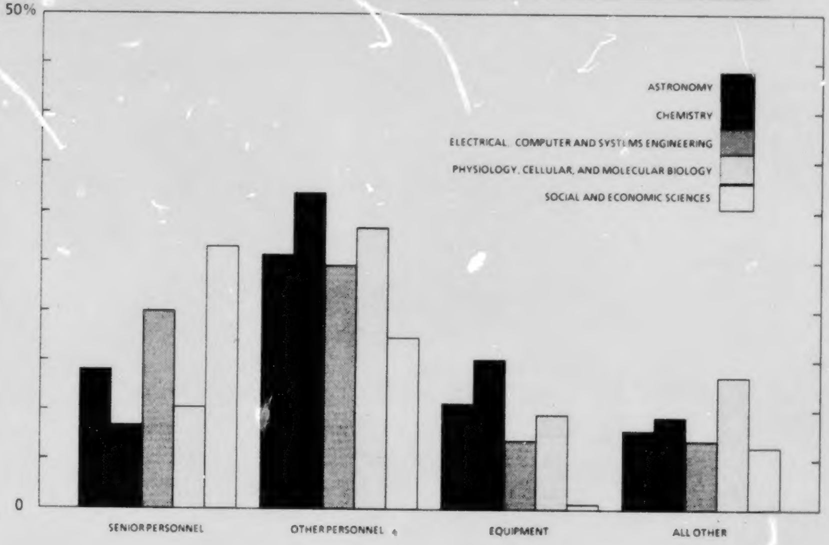

Distribution of Direct Costs in Research Awards

The charts above display a comparison of direct costs for personnel and for equipment in research grants awarded in the mathematical and physical sciences and in the social and economic sciences by the National Science Foundation during fiscal years 1981 and 1982. In the social and economic sciences, equipment makes up a miniscule portion of direct costs of awards. Costs for senior personnel in the social and economic sciences, however, exceed 25 percent of such awards.

Mr. Walgren. On another subject, I know that, Dr. Knapp, in your presentation you rather carefully segregate your presentation to NSF's role in graduate, and then go to precollege as a sequence in defining NSF's role. I would like to ask how that emphasis—in contrast to that, Dr. Branscomb lays out a somewhat broader role of the principal functions of NSF.

In particular, on page 2 of his statement he says that, recognizes the role to "encourage the highest quality of education in scientific and engineering research and practice."

What I would like to ask is the degree of receptiveness in your view as Director of NSF to the thrust of this bill which the Science and Technology Committee marked up last week. Part of H.R. 1310 ask the NSF to provide educational programs for technician training. This is in view of the fact that in terms of establishing the effectiveness of engineering practice in our society we are at a time when the national interest clearly requires the development of broad-based technician capability.

As you know, in H.R. 1310 we provide on a matching grant basis for the NSF to engage in model technician training programs through the community colleges. I note the fact that your statement does not really address that level of NSF's involvement.

I would like to ask the receptivity of NSF for that thrust.

Dr. Knapp. I would say that in many ways the problem could be characterized as similar to the precollege program. It is a problem of curriculum, perhaps curriculum development, in the training of teachers in community colleges for technician training programs in the basic sciences.

The Foundation would be receptive to working out programs of that kind, as it has done previously in precollege education.

Mr. Walgren. I appreciate that very much. Just as Mr. Brown is not above a partisan comment from time to time, I just would propose the following. Going back to our previous discussion of the effort in science education, and the view that somehow or other this had dwindled through the 1970's, and we came up to a point when it was so fragmented that it had to be essentially terminated in order to be set right.

I had two thoughts that I ought to throw out. One is that the degree of dwindling is not absolute. We were at $80.6 million in 1981, in actual expenditures in that area. We had hit a high of $150 million sometime during the mid-1970's.

So when this function was essentially zeroed out, it had only dwindled less than about one-half of its maximum effort. I also question whether it is valid criticism of the program that it was fragmented, because that characterization also applies to the other programs that the National Science Foundation carries out.

I found when that attack was made that there must—well, that that was not sufficient justification for turning away from a program. In particular, in the math and physical sciences, we have 43 separate programs. In engineering, we have 24. In astronomical and atmospheric, we have 28. In science education, we had—how many?—27, or thereabouts.

So I just don't like, or don't want to be silent in any way when the thought is expressed that somehow or other there was not a very abrupt change in the approach that we took as a Government toward science education in 1981.

Dr. **Branscomb**. I would say only that there is a difference between explanation and advocacy. In my comments on that subject, I have been trying to explain what happened, not advocate it.

It is in the interests of the country to see what is now emerging as a consensus to this issue. To take full advantage of the consensus, we will be well served by not focusing on 1980-81. Let's focus on 1983-84.

In that spirit, I certainly don't contest your comment. Many of the programs in place in 1980-81 obviously were helpful and useful. The Summer Institutes were an example of a program that reached a sufficiently large fraction of the teachers in particular disciplines. That program really did cover the country. It undoubtedly helped a lot to make things better than they would have been. But somehow I think we were all under the illusion that we were solving the problem when the problem was getting worse.

In that sense, I think the need for a fresh consensus and fresh look through a body like the Commission was in order. I take considerable satisfaction in the existence of the new consensus.

Mr. **Brown**. Mr. Chairman.

Mr. **Walgren**. Mr. Brown.

Mr. **Brown**. Could I have just another minute or two to explore another issue?

Mr. **Walgren**. Yes.

Mr. **Brown**. First, let me concur with the expression you just made, Dr. Branscomb. There is no real point in belaboring 1981 and 1982 when we can emerge into a fresh start here.

I want to follow up just briefly on the comment that Mr. Mineta made which he referred to the need to take longer range looks at some of these policy issues and the manpower issue is one.

There are similar issues. This is not a new matter for the committee, as you know. Mr. Mineta will find out fairly quickly the background of many years that we have spent belaboring this question. As you know, the Science Policy Act of 1976 made some effort to address this through the requirement for 5-year outlook in science, and some related kinds of policy directions were written into the act.

I still feel we have a useful structure here, but one that has not been fully implemented or exploited. A large part of that responsibility has been laid off on you, Dr. Knapp, in your role as NSF Director by delegation from the Science Adviser, as I understand it.

Now, I still believe that a good part of our problem here, and it has been expressed by several members, is the lack of a coherent policy guidance structure which inherently doesn't seem to come too well from Presidents or Congress as a whole or individual Members of Congress because of the changeable and political nature of their role.

There needs to be an institutional commitment to a certain amount of long-range policy foresight which needs—and we need to strengthen that.

This is one of the fundamental areas where we are not competitive with some of our friendly neighbors in other countries, and in which we ought to try and become competitive without adopting the evils of their system of too much guidance of the free enterprise system and so on.

But we do need policy leadership, and we need to have that formulated. Now, I would suggest, as I suggested earlier to Dr. Branscomb in the field of informatics, or computer and telecommunications, that the question of how we provide overall guidance to science and technology and its role in our society, the interrelationships between it and education, and between industry and universities, the subject of your last report, could perhaps benefit from a high level examination and the development of a policy posture aimed at building on what is already in the law, or strengthening it or modifying it or doing whatever else might be desirable here, instead of floundering.

I would hope that in some constructive way the Foundation and the Board would give consideration to that. Believe me, we in Congress understand our limitations in terms of creating long-range forecasts and long-range policy.

We need an institutional structure to do that. We have such confidence in the Foundation and the Board that I think we would look with a great deal of receptivity on your approaching that problem in some fashion and working with the Science Adviser.

If it requires the involvement of a group of prestigious nongovernmental people, the Commission is one way to approach that. I think it would be worthwhile for you to at least give that some thought. If it turns out that it is a critical problem, and a crisis develops as a result of it, you know what Congress will do.

We will shove some institutional structure down your throat. It probably wouldn't be very good. We will say we have responded to the crisis.

Really, it is just a shot in the arm, may not have much permanent value to it. So, I commend that to your consideration for what it may be worth as a possible initiative.

Dr. **Branscomb**. Mr. Brown, the Board has debated that subject a great deal in the last year. We have work in place now to carry the debate further. We are aware we have some limitations, too, but we don't have a good excuse for not trying to overcome them.

I think the Board has made some progress. The real question is getting the menu for this meal divided into an appropriate number of courses so that we don't try to eat the whole menu all at once.

Mr. **Brown**. Sure.

Dr. **Branscomb**. But the Board does owe you a better job than it has done of showing you how the pieces fit together. That's difficult. The Board has done a study in the field of university-industry relations. We see a lot of dynamics there. We are going to do another in international science.

It's not clear to me yet how we will show you the relationship between those two issues, for example, and of course they also relate to education and other matters. But I also know that the Director has given the same issue—how can we do a better job of policy analysis on our own—a good bit of thought. We will certainly take your advice to heart.

Mr. **Brown**. In another area, agriculture, which you referred to, it will be a part of my role as chairman of the appropriate subcommittee there to look at the institutions of agricultural research during the next 2 years.

What we find in almost any institutional framework is a desire to protect the institution more than to look at the national purpose for which the institution was created.

NFS is not beyond falling into that same trap. It would be unfortunate if it did, because it was created to serve the highest interests of the Nation. I think we would all like to see it fulfill that goal.

Mr. **Walgren**. Thank you, Mr. Brown. Well, thank you very much. We enjoyed it.

Dr. **Branscomb**. Thank you, Mr. Chairman.

Dr. **Knapp**. Thank you.

Mr. **Walgren**. The next witnesses are Jon W. Fuller, the president of Great Lakes Colleges Association, and Saul Fenster, president of the New Jersey Institute of Technology. I want to apologize to the witnesses for having extended the conversations with the people just preceding.

But, as you know, we don't see them that often and it's important to try to give all the members a chance to fully develop their lines of inquiry. We look forward to your testimony. The written testimony will be made a part of the record. Please summarize or communicate with the committee as best as you see fit.

Let's start with Dr. Fuller.

STATEMENTS OF DR. JON W. FULLER, PRESIDENT, GREAT LAKES COLLEGES ASSOCIATION, AND SAUL FENSTER, PRESIDENT, NEW JERSEY INSTITUTE OF TECHNOLOGY

Dr. **Fuller**. Thank you, Mr. Chairman. I appreciate the chance to appear. I am representing the 12 colleges that make up the Great Lakes Colleges Association but I want to speak more broadly about the role of the undergraduate college in science education. I think it is appropriate that undergraduate education has the special focus of a separate witness because, frankly, it has been a neglected part of the continuum of science education in recent years.

These are institutions with a very high productivity of teachers of science and research scientists. I was pleased that Dr. Knapp, in his comments this morning, referred to that productivity. I would like, Mr. Chairman, to provide for the record a recent study that documents that.

[The information follows:]

BACCALAUREATE ORIGINS OF DOCTORATES IN THE PHYSICAL AND BIOLOGICAL SCIENCES

The smaller colleges have traditionally and consistently been highly productive of students who go on to get their Ph.D. degrees in the sciences. In the most recent period for which we have data, graduates of the Associated Colleges of the Midwest and Great Lakes Colleges Association member colleges continue to receive their Ph.D. degrees in the physical and biological sciences at rates of increase that compare favorably to those of the ten leading sources of Ph.D. degrees and eight leading technical schools.

Although for the most recent period, 1977-80, the average yearly production for all colleges and universities in our study is down slightly from the next most recent period, 1967-76, all in the group show increased productivity from the base period, 1950-59. The ten leading baccalaureate sources of doctorates increased their average yearly output 141.5 per cent and eight leading technical schools by 45.6 per cent, while the ACM colleges increased their productivity by 209.2 per cent and the GLCA colleges by 85.9 per cent.

Sources:

1950-59 figures: "Changes in Baccalaureate Origins of Doctorates in the Sciences," Albert B. Stewart, Antioch College, January, 1967.
and
Doctorate Production in United States Universities, 1920-1962, Publication 1142, National Academy of Sciences - National Research Council, 1963, Appendix 5.

1960-66 figures: Doctorate Recipients from United States Universities, 1958-1966, Publication 1489, National Academy of Sciences, Washington, D.C., 1967, Appendix B.

1967-76 figures: "CY 1920-FY 1976 Doctorates by Baccalaureate Institutions in 31 Doctoral Fields, 3 Time Periods," unpublished statistics by the National Academy of Sciences, Washington, D.C., 1977.

1977-80 figures: Baccalaureate Origins of Doctorate Recipients from U.S. Universities, 1977-1980, Doctorate Records File, National Research Council, 1982.

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SUMMARY TABLE

BACCALAUREATE ORIGINS OF DOCTORATES IN THE PHYSICAL AND BIOLOGICAL SCIENCES

Baccalaureate Source of the Ph.D.	10 Years 1950-59 Yearly Average	7 Years 1960-66 Yearly Average	10 Years 1967-76 Yearly Average	4 Years 1977-1980 Yearly Average	Percentage Increase in Yearly Average Between 1950-59 and 1977-1980
Associated Colleges of the Midwest 2/	33.8	62.7	111.5	109.3	209.2 1/
Great Lakes Colleges Association 3/	65.9	94.1	156.0	122.5	85.9
Eight Leading Technical Schools 4/	205.6	389.2	618.6	496.5	141.5
Ten Leading Sources 5/	678.0	847.8	1230.9	987.0	45.6

1/Increase based on difference between 1977-80 yearly averages minus Lake Forest College and 1950-59 yearly averages, for which period Lake Forest figures are not available.

2/The Associated Colleges of the Midwest are: Beloit College, Carleton College, Coe College, Colorado College, Cornell College, Grinnell College, Knox College, Lake Forest College, Lawrence University, Macalester College, Monmouth College, Ripon College, St. Olaf College.

3/The Great Lakes Colleges Association members are: Albion College, Antioch University, Denison University, DePauw University, Earlham College, Hope College, Kalamazoo College, Kenyon College, Oberlin College, Ohio Wesleyan University, Wabash College, The College of Wooster.

4/Eight Leading Technical Schools are: Massachusetts Institute of Technology, California Institute of Technology, Rensselaer Polytechnic Institute, Rice University, Lehigh University, Illinois Institute of Technology, Polytechnic Institute of New York (name changed from Brooklyn Polytechnic in 1973-74), Virginia Polytechnic Institute and State University.

5/Ten Leading Sources include: University of California-Berkeley, CUNY-City College (formerly City College of New York), University of Illinois, University of Chicago, University of Wisconsin, Harvard University, University of Minnesota, University of Michigan, Columbia University, Cornell University.

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BACCALAUREATE ORIGINS OF DOCTORATES IN THE PHYSICAL AND BIOLOGICAL SCIENCES

ASSOCIATED COLLEGES OF THE MIDWEST

Baccalaureate Source of the Ph.D.	10 Years 1950-59		7 Years 1960-66		10 Years 1967-76		4 Years 1977-1980		Percentage Increase in Yearly Average Between 1950-59 and 1977-1980
	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	
Beloit	32	3.2	43	6.1	75	7.5	32	8.0	150.0
Carleton	50	5.0	74	10.6	215	21.5	91	22.8	356.0
Coe	17	1.7	18	2.6	34	3.4	18	4.5	164.7
Colorado	24	2.4	27	3.9	89	8.9	30	7.5	212.5
Cornell	28	2.8	26	3.7	60	6.0	19	4.8	71.4
Grinnell	38	3.8	50	7.1	131	13.1	39	9.8	157.9
Knox	21	2.1	32	4.6	107	10.7	43	10.8	414.3
Lake Forest	unavailable		7	1.0	33	3.3	19	4.8	unavailable
Lawrence	23	2.3	24	3.4	66	6.6	34	8.5	269.6
Macalester	20	2.0	17	2.4	78	7.8	22	5.5	175.0
Monmouth	26	2.6	18	2.6	50	5.0	19	4.8	84.6
Ripon	8	0.8	23	3.3	42	4.2	14	3.5	337.5
St. Olaf	51	5.1	80	11.4	135	13.5	57	14.3	180.4
TOTAL	338	33.8	439	62.7	1115	111.5	437	109.3	209.2[1]

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[1] Total increase based on difference between 1977-1980 yearly averages minus Lake Forest College and 1950-59 averages, for which period Lake Forest figures are not available.

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BACCALAUREATE ORIGINS OF DOCTORATES IN THE PHYSICAL AND BIOLOGICAL SCIENCES

GREAT LAKES COLLEGES ASSOCIATION

Baccalaureate Source of the Ph.D.	10 Years 1950-59		7 Years 1960-66		10 Years 1967-76		4 Years 1977-1980		Percentage Increase in Yearly Average Between 1950-59 and 1977-1980
	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	
Albion	17	1.7	25	3.6	83	8.3	29	7.3	329.4
Antioch	61	6.1	62	8.9	127	12.7	51	12.8	109.8
Denison	31	3.1	20	2.9	60	6.0	39	9.8	216.1
DePauw	97	9.7	58	8.3	142	14.2	30	7.5	-22.7
Earlham	21	2.1	33	4.7	140	14.0	34	8.5	304.8
Hope	47	4.7	42	6.0	135	13.5	29	7.3	55.3
Kalamazoo	43	4.3	38	5.4	119	11.9	38	9.5	120.9
Kenyon	19	1.9	26	3.7	66	6.6	23	5.8	205.3
Oberlin	181	18.1	179	25.6	279	27.9	94	23.5	29.8
Ohio Wesleyan	36	3.6	52	7.4	108	10.8	31	7.8	116.7
Wabash	42	4.2	56	8.0	126	12.6	26	6.5	54.8
Wooster	64	6.4	67	9.6	175	17.5	66	16.5	157.8
TOTAL	659	65.9	658	94.1	1560	156.0	490	122.5	85.9

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BACCALAUREATE ORIGINS OF DOCTORATES IN THE PHYSICAL AND BIOLOGICAL SCIENCES

EIGHT LEADING TECHNICAL SCHOOLS

Baccalaureate Source of the Ph.D.	10 Years 1950-59 No. of Ph.D.s	Yearly Average	7 Years 1960-66 No. of Ph.D.s	Yearly Average	10 Years 1967-76 No. of Ph.D.s	Yearly Average	4 Years 1977-1980 No. of Ph.D.s	Yearly Average	Percentage Increase in Yearly Average Between 1950-59 and 1977-1980
M.I.T.	735	73.5	1102	157.4	2296	229.6	765	191.3	160.3
Cal Tech	365	36.5	356	50.9	729	72.9	287	71.8	96.7
Rensselaer	233	23.3	334	47.7	894	89.4	270	67.5	189.7
Rice University	127	12.7	210	30.0	548	54.8	175	43.8	244.9
Lehigh University	130	13.0	185	26.4	405	40.5	138	34.5	165.4
I.I.T.	171	17.1	173	24.7	369	36.9	106	26.5	55.0
Polytechnic Institute of N.Y.[1]	142	14.2	220	31.4	489	48.9	80	20.0	40.8
V.P.I.	153	15.3	145	20.7	456	45.6	165	41.3	169.9
TOTAL	2056	205.6	2725	389.2	6186	618.6	1986	496.5	141.5

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[1] Name changed from Brooklyn Polytechnic Institute in 1973-74 academic year.

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BACCALAUREATE ORIGINS OF DOCTORATES IN THE PHYSICAL AND BIOLOGICAL SCIENCES

10 LEADING SOURCES

Baccalaureate Source of the Ph.D.	10 Years 1950-59		7 Years 1960-66		10 Years 1967-76		4 Years 1977-1980		Percentage Increase in Yearly Average Between 1950-59 and 1977-1980
	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	No. of Ph.D.s	Yearly Average	
U. Cal.-Berkeley	1065	106.5	849	121.3	2041	204.1	723	180.8	69.8
CUNY-City College[1]	862	86.2	690	98.6	1328	132.8	258	64.5	-25.2
U. Illinois	843	84.3	843	120.4	1685	168.5	536	134.0	59.0
U. Chicago	590	59.0	344	49.1	491	49.1	181	45.3	-223.2
U. Wisconsin	655	65.5	586	83.7	1271	127.1	473	118.3	80.6
Harvard	564	56.4	479	68.4	944	94.4	257	64.3	14.0
U. Minnesota	539	53.9	529	75.6	1079	107.9	305	76.3	41.6
U. Michigan	623	62.3	574	82.0	1367	136.7	487	121.8	95.5
Columbia U.	394	39.4	399	57.0	646	64.6	156	39.0	- 1.8
Cornell U.	645	64.5	642	91.7	1457	145.7	572	143.0	121.7
TOTAL	6780	678.0	5935	847.8	12309	1230.9	3948	987.0	45.6

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[1] Formerly City College of New York

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Dr. **Fuller**. Despite the fact that these undergraduate institutions have played an important role in producing our scientists and our teachers of science, despite the fact those 4 years of undergraduate education are a crucial time where students make career choices to follow these kinds of scientific careers that are so important, we have not found the kind of attention from the NFS or National Science Board that we think is appropriate to this part of the educational continuum.

As I listened to Dr. Branscomb this morning, I was disappointed but not surprised that in talking about science education for a couple of hours he managed to talk about pre-college education and he managed to talk about graduate education, and not once did he mention undergraduate education.

I think that may reflect the fact that in the National Science Board membership you will find there is now no one with current, firsthand experience with undergraduate education and the crucial role it plays. That may be reflected in the fact it is not visible in Dr. Branscomb's considerations.

As Dr. Knapp said this morning, the process of science education is a continuum. And we think that the undergraduate colleges have an important role to play. They need some kind of support as part of the Federal effort in supporting science and science education.

About a month ago we brought together a number of our best science faculty members and spent a day with them. I am basing my testimony really on what they told me in that day's conference about the kind of help they need to do the job which we have done in the past and which we need to continue to do.

The first item for them was opportunities for research for undergraduate faculty. First of all, that is important to them as scientists, to be able to continue active research. Second, when it is done by undergraduate faculty, it inevitably involves undergraduate students. That is part of the process. That is one reason for the high productivity of scientists from these institutions. An undergraduate who gets involved in first line research at that point in his career has an excitement and taste for science that simply can't be matched when it comes later, as it always does, as part of the graduate program. We think that is one of the keys.

There is a double advantage of research done by a faculty member at a predominantly undergraduate institution because the student receives a kind of educational advantage at that level at the same time the research itself is done.

We find Dr. Knapp seems to understand that, both in conference with him and in his testimony. We are pleased by that. We have suggested that some kind of a small setaside may be essential to assure that the research proposals that come from undergraduate faculty members have a fair hearing, the setaside serving simply as a standard that we are getting an appropriate level of attention at this level.

It may be that the undergraduate college research support programs Dr. Knapp is proposing this year will function in those ways, a small setaside. The full outline is not clear yet. We would like to suggest that we need at least some kind of standard that will say undergraduate faculty are not neglected in this reseach funding process.

Second, our faculty members need regular opportunities for professional renewal. In a small college they inevitably teach a broader range of courses than in the case of a major university. They need a chance to fill in not only their knowledge of their own area of specialization and research, but also the other areas they teach.

There have been some useful programs in the past at the NFS such as the science faculty fellowships. We think that something of that sort is going to be needed. It appears that, again, this new undergraduate college research support program will include some of those elements. We think the proposed funding level of $3 million is probably considerably too low given the need there, but we do appreciate at least a recognition from the Foundation that this is important.

Third, our people tell us one of their important needs is instrumentation for instruction. The Foundation has appropriately come up with a very large increase in instrumentation support but it is all defined as research support. Particularly the predominantly undergraduate college needs a chance to acquire some equipment which will be used primarily for instruction and will not have a role in the research of particular faculty members there.

We would hope you would include that and keep it in mind as you talk about the total instrumentation program. One kind of equipment in a category by itself, as you will understand, is computing equipment. One of the problems we have in dealing with the instrumentation support we can presently get from the NFS for computing equipment is that its application, particularly with the undergraduate college, cuts across almost every discipline.

The Foundation tends to receive and judge its proposals in terms of particular disciplines. We think a different focus is needed when we talk about computing and support for computing equipment at the undergraduate level for many disciplines.

Finally, we think there is a need for periodic review at the undergraduate level, as well as the graduate level, in the methods of teaching science. In particular, I would suggest to you we need to have some programs that will help us in bridging some of the disciplinary boundaries which are cut apart at the Federal level as much as they are at the university and college level.

When we want to talk about the general issue of technological literacy leading to a population that can cope with the kind of society in which we are going to live, that involves not only the knowledge of science but of its applications and its ethical implications—of its implications for the kind of lives we live, implications for our economy and our political system.

We would suggest that, for example, the National Science Foundation and the National Endowment for the Humanities might be encouraged to fund some collaborative projects that would deal with those much broader issues which we think are important in terms of public understanding of science and the role it is going to play in our society.

As I said, we are very appreciative that we have in the Director of the Foundation, finally, someone who does seem to understand the role of the undergraduate college and some of its special needs.

We would suggest that what is being proposed under the title of "Undergraduate College Research Support" is certainly appropriate as an initial response to this. We would hope that it might be more generously funded than the present budget provides.

One particular point about the program is unclear in the materials available from the Foundation so far. Research support given to undergraduate faculty members should, wherever it is appropriate—and it usually is, if not in every discipline, in a great many of them—be carried out on the undergraduate campus and not require the faculty member to go to some other laboratory where the students can't go along. There is an important benefit to having the students involved as much as possible in that faculty member's research.

We have appreciated the support that this committee has given to science education generally and an understanding on the part of this committee over the years that the undergraduate phase of the science education continuum was important. We have regretted that we haven't had the kind of responsiveness in the National Science Board and the National Science Foundation that we think is appropriate. I admit I am concerned that Dr. Knapp may find himself feeling a little lonely with his special concern for undergraduate colleges as he deals with the other people in his agency. We hope the committee will continue to monitor his success and find ways to support his efforts there.

There is one other program that I would like to make a quick comment about. It is not likely to be a direct help to most of the colleges I represent but it is important in terms of our concern about the status of science education generally, and that is the precollege teacher improvement in science and mathematics, the summer workshops. We are sorry to see that there seems to be some concern on the Senate side about the proposal for the fiscal year 1983 funding for this. We hope that can be resolved because we think it is very important that the National Science Foundation have a central role in addressing the problems of precollege science education.

Science education requires the active involvement of scientists, and the Department of Education can't provide that. They can administer formula grants and work with the State agencies, but when you are going to talk about the content of those institutes and when you are going to talk about deciding which are the best among the proposals, you need the expertise that comes from the National Science Foundation. You are not going to find comparable expertise in the Department of Education. So we would urge you to insist, as I understand you already have, that the NSF have an active role in that phase of the science education effort.

I appreciate the opportunity to appear before this committee and when Dr. Fenster is finished I will be happy to respond to questions.

[The prepared statement of Dr. Fuller follows:]

Prepared Statement of Jon Fuller, President, Great Lakes Colleges Association

Mr. Chairman:

I am pleased to have been invited to appear before this committee as you consider the fiscal year 1984 authorization for the National Science Foundation. In appearing here today, I am representing the twelve undergraduate liberal arts colleges which are members of the Great Lakes Colleges Association.* These institutions are proud of their past record and their continuing role in producing research scientists and teachers of science for our nation. The contributions of these institutions in terms of the high quality of their graduates may be even more important than their demonstrated productivity in numbers. At the undergraduate level the apprentice-mentor relationship, which is the best way for young scientists to learn about science, is most likely to occur at the undergraduate college. The education of scientists in liberal arts colleges is further enhanced as they learn their science within the context of the broader range of the liberal arts.

It is extremely important that the process of science education and of the education of scientists be seen as continuous. The undergraduate years represent a crucial phase in that process, when qualified students consider and choose careers in science. In the federal concerns about scientific literacy for our population, and about the production of trained scientific manpower, the role of quality undergraduate colleges needs to be kept clearly in mind and to be supported in direct and appropriate ways. What kinds of support do these colleges need in order to continue their important role in the education of scientists?

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* Those colleges are DePauw, Earlham, and Wabash in Indiana; Albion, Hope and Kalamazoo in Michigan; and Antioch, Denison, Kenyon, Oberlin, Ohio Wesleyan, and The College of Wooster in Ohio.

They need, first, opportunities for research by faculty members at these colleges. The faculty members at quality undergraduate colleges can and do carry on research of the highest quality, and their continued vitality as researchers is directly connected to their effectiveness as teachers of science. We believe that research by these faculty members should be supported through a small set-aside in the general NSF budget. Frankly, there has been a perception on the part of many fine scientists teaching at undergraduate colleges that there has been some prejudice in the review of their research proposals at the National Science Foundation. Most of NSF's dealings are, quite appropriately, with the major research universities. Those who review proposals do not always seem to understand that top-quality research can be and is done by faculty at colleges where the major emphasis is on teaching. Indeed, it is carried on as an extension of teaching, involving the most promising undergraduates, and this is one of the reasons that the support of research by faculty at undergraduate teaching colleges has a double value: the quality of the research itself, and the contribution it makes to the education of some of our best future scientists. While we would continue to insist that only the best proposals for research be supported, we believe that a small set-aside would provide an appropriate standard to be sure that proposals from undergraduate institutions are not neglected.

Secondly, faculty at predominantly teaching institutions need periodic opportunities for professional renewal. They need to work with and consult with scientists at larger laboratories, as a supplement to the research activity which they can carry on on their own campuses. Faculty at undergraduate colleges are called upon to teach a broader range of courses than are colleagues at larger and more specialized institutions, and they have some special needs in keeping up with a wider field of knowledge. The Science Faculty Fellowships of the past fulfilled this need by providing undergraduate faculty support to spend time in industrial or academic research settings. The Small

College Faculty Opportunity program, which NSF proposes to absorb in the new Undergraduate College Research Support Program, also meets a part of this need.

Third, there are important instrumentation needs for both research and instruction. Some equipment is in the natural course of things acquired initially for research purposes and then used for instruction. But there is also a need in many fields for state-of-the-art equipment which will be used primarily for instruction. That need is not now being adequately met from any source.

In providing federal assistance in the purchase of larger scale and expensive equipment for use in instruction, it may be useful to require the institution to share significantly in the cost of that equipment. Total needs in scientific instruction are great, and some form of rationing for scarce resources is required. When the institution bears a significant part of the cost, this insures that the equipment will be placed where it is going to be used.

There is one type of scientific equipment which is clearly in a category to itself, and that is computing equipment. It differs both in its scale and the very broad applications throughout the work of a college or university. It is important that support for the acquisition of computing equipment not be penalized precisely because it is so broadly useful across the range of disciplines. Where such support is organized primarily by individual disciplines, this can be the case. There is a need for some support categories that will respond to major equipment needs, particularly in computing, which cut across most disciplines.

Finally, there is a need for the periodic review and improvement of science instruction. The National Science Foundation, in the past, has provided useful support for this need to keep curricula current with the ever-changing state of scientific knowledge. Such improvement on every level of science education is a high priority now.

As undergraduate liberal arts colleges, we are particularly aware that there are important curricular projects which are comprehensive, bridging the sciences, the social sciences and the humanities. The divisions of responsibility in the federal government hinder appropriate assistance to colleges and universities with valuable projects which cross disciplinary lines. It would be very desirable to have an encouragement of regular NSF-NEH collaboration in projects of high quality which do bridge disciplines. This is particularly applicable in our concerns about general technological literacy. Such programs contribute not only to the training of manpower for science and technical components for our society, but also to the transmittal of the broad understanding of science which is increasingly needed for effective democratic government in a technological age.

We have appreciated Director Knapp's recognition of the important role of undergraduate colleges. As he put it in this year's NSF budget summary: "Another crucial part of the link in the educational base which provides the Nation's future engineers and scientists is the small, predominantly undergraduate college. A significant proportion of those awarded the PhD in science, mathematics and engineering receive their baccalaureate at these institutions." He goes on to note that "it is important that faculty of these institutions receive support and encouragement for maintaining their research capabilities." For this purpose, the National Science Foundation is proposing this year to spend three million dollars on a new program under the title "Undergraduate College Research Support." We would suggest first that it be very clear that research supported under this program shall, whenever appropriate, as it very often is, be carried out on the undergraduate campus. In some cases undergraduate faculty may need the resources of a larger laboratory at a major research university or independent laboratory.

But whenever the research can be carried out on the undergraduate campus, there is the double advantage of more sustained involvement by the faculty member doing the research and also the very important involvement of the best undergraduate students in assisting with that research.

We would also suggest that although there seems to be no line item for this effort, there does need to be specific statutory language directing this effort and identifying its level of support. We greatly appreciate Dr. Knapp's understanding of the importance of undergraduate institutions. But we are painfully aware that this is a rather new line from the National Science Foundation. Despite the clear language of the statue which created the Foundation, and despite the persistent urging of this committee and other parts of the Congress, the plain fact is that the National Science Foundation has given clearly inadequate support to its responsibilities for science education and for the education of scientists for the future.

We are also aware that there is no sharp distinction to be made between research and education in the sciences. They support each other, and often go on simultaneously. But we believe that direct statutory language is needed to remind the National Science Foundation that its education responsibilities are important and need to have explicit support.

We would like to comment on one other element of the NSF budget which has been proposed by the Administration. That is the intention to fund Pre-College Teacher Improvement in Science and Mathematics, carried out through in-service teacher institutes, at a level of 19 million dollars. In addressing the issues of education in science and mathematics at the elementary and secondary level, which I realize has been a special concern of this Committee this year, we would emphasize both the desirability and the necessity for the direct involvement of the National Science Foundation in teacher training and curriculum development for the elementary and secondary schools. Our needs in science education are not only needs in terms of numbers but also in terms of the quality of education. Quality science education requires the direct involvement of scientists. We believe it is most appropriate that the lead in the specialized training of teachers for their responsibilities in teaching science should come at the federal level from the National Science Foundation.

We appreciate this opportunity to appear before the Committee and to offer these particular views from the perspective of the quality undergraduate college.

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Mr. **Walgren**. Thank you very much, Dr. Fuller. That was a very comprehensive presentation.

Dr. Fenster.

Dr. **Fenster**. Thank you very much. I will try to be brief and give you an abbreviated version of my full testimony which you have.

I am delighted to have this opportunity to appear before the committee and to testify on the fiscal 1984 NSF authorization and bill today, giving particular emphasis to science and engineering education. I represent 354 member institutions of the American Association of State Colleges and Universities, and I am currently vice chairman of its Committee on Science and Technology.

I am also speaking on behalf of the 20 associations who participated in the development of the higher education agenda on science, mathematics, and technology education. The committee is, of course, well aware of the current national crisis in science, mathematics, and technology education.

During the course of your recent hearing on H.R. 1310, testimony was introduced that pointed to the decay in our scientific educational system. There was documentation of declines in student achievement in mathematics and sciences, documentation of a serious shortage of qualified mathematics and science teachers, documentation of a vacancy in faculty positions and university engineering departments of about 2,000. We have a vacancy factor of about 10 percent in our engineering faculty at NJIT, which corresponds to that national figure. Documentation of the obsolescence of much of the instrumentation and equipment used in college and university laboratories.

Since 1972 there has been a 54-percent decline in the number of Ph. D.'s awarded in engineering yearly to U.S. nationals. Here I might add that in our own experience where we have supplemented institutional fellowship support and fellowship support obtained through corporate fundraising, we have been able to significantly improve the percentage of U.S. nationals enrolled in full-time graduate studies.

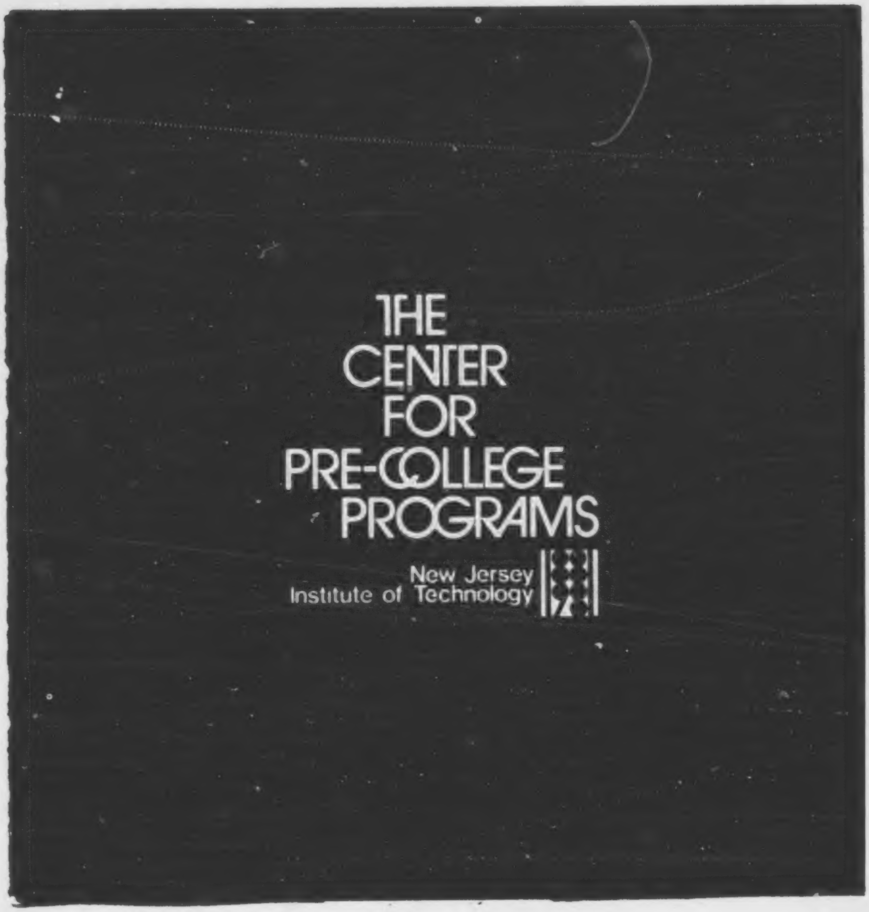
Although there is now general agreement on the dimensions of the problem, there is no consensus on the solution. Constructive actions at the institutional, local, State, and national levels are necessary to forestall a further deterioration. The NSF support of science and engineering education has been crucial to my institution. Currently NJIT has a large and successful center for precollege programs.

Here I might interject we spoke of the continuum. I think earlier there was a discussion of the continuum. At my institution there may be at least some elements of uniqueness in that the continuum ranges from a precollege program which starts at grade 7 through the doctoral programs through postdoctoral continuing professional education programs. So I think that while we are very, very heavily involved in undergraduate education, which represents over three-quarters of our enrollment, we are very sensitive of the needs of the continuum and having strength and vigor in each aspect of the continuum.

The aim of our precollege programs at NJIT is to provide disadvantaged students, many of them from minority groups, with the technical skills necessary to pursue careers in the sciences and engineering. It is a very demanding program, but over 90 percent of our participants successfully complete and go on to college. It is not a recruiting program for NJIT—although we are very delighted that many of these students, in fact, enroll as undergraduates at NJIT—but it is a recruiting program for science and technology, if you will.

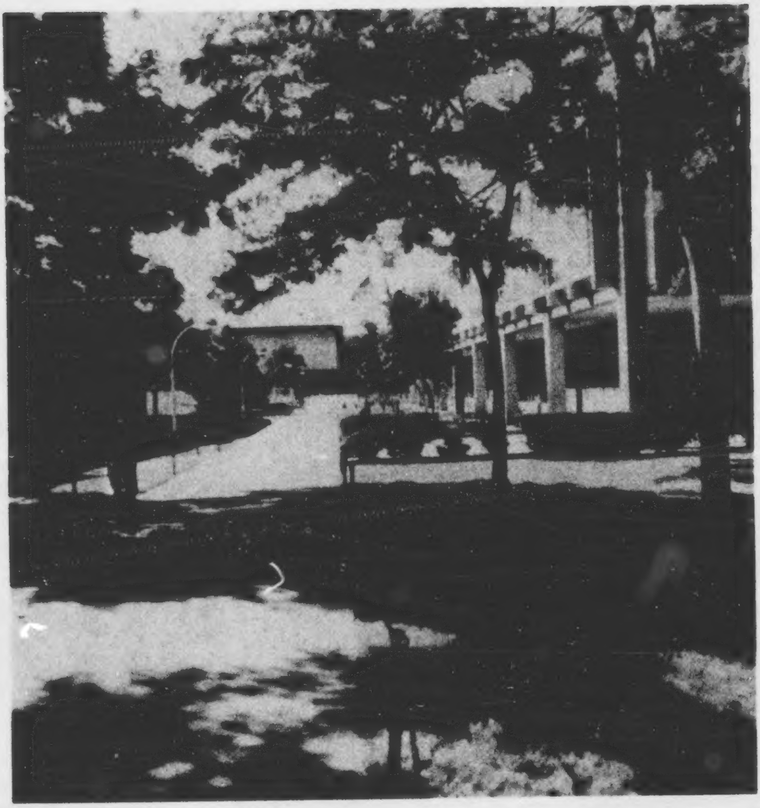
If I may, Mr. Chairman, I would like to introduce a report of the Center for Precollege Programs at the New Jersey Institute of Technology which details the various programs under the Center and the distribution of students enrolled in them.

[The report follows:]



THE CENTER FOR PRE-COLLEGE PROGRAMS

New Jersey
Institute of Technology



INTRODUCTION

A decade has passed since New Jersey Institute of Technology offered its first on-campus program for high school students. Whereas in 1971 only 40 students participated, now more than 1,000 take courses, mini-courses and workshops at NJIT. Advances in technology, rapid growth in the fund of knowledge, and a myriad of socio-economic changes have altered the student's view of the world immeasurably in a short span of years. Pre-college program students of the early 70's are now practicing engineers, technologists and computer scientists. They are doctors and attorneys, rising managers and businessmen and women. Several are teachers who send students to the programs. These young people set a high standard of participation and achievement. Their success encouraged the Institute to develop the variety of programs that are offered today.

Pre-College programs of the 80's respond to the times. Problems of our cities have not diminished and the urban environment is very much a focus. Several programs are concerned with effective use of limited natural resources and development of alternate sources of energy. Computers are no longer the way of the future, they are a part of everyday life. Thus computer programming and program design have become increasingly important elements of individual programs. The management of hazardous wastes, bio-medical engineering, and applications of technology assessment are areas of study important to society. These same areas are of increasing interest to students. They offer direction for developing new pre-college programs.

New programs introduced at the advent of the eighties expanded understanding of technology at work. An Energy & Environmental Technology Workshop for teachers attracted 50 teachers from nine New Jersey counties. Research apprenticeships gave five superior students an opportunity to work directly with faculty researchers. The Chemical Industry Minority Engineering Program gave 23 students a working knowledge of chemical engineering at the same time it served as a prototype for future programs at other institutions. An introduction to Urban Engineering for Junior High School Students is the realization of a goal; reaching students when counseling and career information can influence high school curriculum selection.

Most pre-college programs are open to all students who demonstrate a good record of achievement in mathematics and science and who are recommended by their teachers. Others are designed in cooperation with specific high schools. All provide direct benefits to the students. Components include academic enrichment and reinforcement, career counseling, college orientation, and personal enrichment through field trips and exposure to guest speakers from business and industry.

Assuming the availability of funding, the Institute intends to continue its array of programs in response to demand. Ultimately a comprehensive sequential program from post-seventh through twelfth grades will be in place. All programs, current and proposed, are dependent on the presence of resources and personnel that ensure the maintenance of quality.

THE CENTER FOR PRE-COLLEGE PROGRAMS

The Center for Pre-College Programs was established in 1979 to coordinate the Institute's expanding number of relationships with secondary school teachers and students. Increased demands on resources and personnel, a need to develop additional funding sources, and a desire on the part of the Institute to involve corporate and secondary school representatives in the activities of the Center all contributed to the decision to adopt the Center format.

An Advisory Board with majority membership from outside the Institute offers leadership and direction to the Center. Board members are concerned with the development of policies and procedures that ensure accountability of individual programs. Cultivation of support from the private sector, both financial and through cooperative participation, is a major function of Board members. The Advisory Board meets quarterly on the NJIT campus.

The Center is affiliated with the Foundation at New Jersey Institute of Technology, a private, non-profit corporation which encourages excellence in education by supporting research, graduate study and public service programs at NJIT. The Foundation is the principal recipient of gifts and grants to the Institute.

Mr. Gerald E. O'Loughlin, General Manager, Business Services of New Jersey Bell Telephone Company, is Chairman of the Advisory Board. Dr. Howard Kimmel of the Department of Chemistry is Director of the Center.

A MESSAGE FROM THE CHAIRMAN OF THE ADVISORY BOARD

It is no secret that business and industry must look more to minorities and women to meet the need for professional personnel in the years directly ahead. During a period when the college-age population is about to decline, the demand for services is expected to increase as the consumer population grows. Blacks, Hispanics and women, currently underrepresented in high demand fields such as engineering and related technological specialties, must have early encouragement if they are to prepare for careers in fields in which they are welcome and needed. Because pre-college programs are most often directed toward these audiences, the private sector would do well to support such programs.

New Jersey Institute of Technology's progress in stimulating interest in the technological fields through programs for secondary school students is an outstanding example of what can be accomplished. A working partnership with the private sector has enabled NJIT to develop meaningful reinforcement and enrichment offerings that annually reach upwards of 1,000 young men and women. As a technological university located in Newark, NJIT has a concentration of special faculty expertise, contemporary physical resources, and a proximity to urban populations important to successful programming.

The record shows that graduates of NJIT's pre-college programs are better prepared to succeed in high education, particularly in curricula where strong background in mathematics and science is vital. Emphasis at NJIT is on participation rather than observation, an important motivational factor in helping participants make personal decisions among many career options.

NJIT's commitment to pre-college programs is firm. So long as qualified personnel and physical resources are available for the continuation of quality programming, the Institute accepts, as part of its public service mission, the creation and support of the Center for Pre-College Programs. NJIT is the vehicle and not the benefactor, and as such requires commitments from the private sector. Modest investments by the private sector are required to make the programs work.

The Center for Pre-College Programs welcomes inquiries from business and industry, large and small. Participation may take many forms. In addition to direct financial support, opportunities are available to host students on field trips, participate in workshops and career programs, sponsor cultural events, or enhance individual programs in other ways.

New Jersey Institute of Technology and those in the corporate community who support pre-college programs extend an open invitation to you to join us.

Gerald E. O'Loughlin
Chairman
Advisory Committee
Center for Pre-College Programs

A MESSAGE FROM THE PRESIDENT OF NJIT

Many of today's young people are intensely curious about how technology relates to their daily lives. Sustaining and nurturing that interest and channeling it into a perspective in which they see themselves as creative professionals rather than observers of a passing scene, is quite another matter.

New Jersey Institute of Technology has long been at the forefront of the nation's institutions reaching out to these youngsters. An array of on-campus programs promote an understanding of technology. Pre-college students at NJIT deal with a range of problem solving activities. They study the urban complex — the problems of air and water pollution and the overall problem of environmental degradation. They propose approaches for improving traffic patterns, creating parks and playgrounds, and generally improving the quality of urban life.

Although NJIT's Pre-College Programs differ from one another, they do share a number of objectives. Academic reinforcement in mathematics and science is built into each program. Communications skills are emphasized as necessary to all endeavors. And the relationship of technology to the people it serves is stressed. Field trips and workshops expose participants to what often is their first glimpse of the working world of professionals. Career counseling and an introduction to a college atmosphere add to their growth as they prepare to make important personal decisions that will affect their future.

We at New Jersey Institute of Technology are concerned that there is a limited presence of Blacks, Hispanics and women in engineering and other technological professions. Special efforts are made to attract minorities and women to the pre-college programs, efforts that have been highly successful.

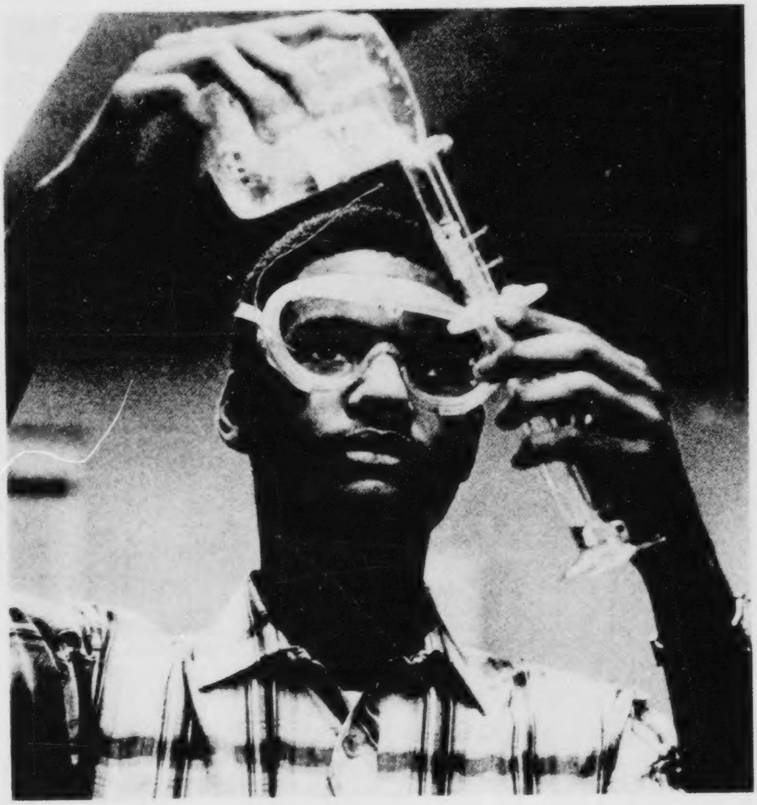
By developing skills and stimulating students to test their interest in science, NJIT is helping to meet the growing need for engineers and technologists.

While most of the Institute's programs are directed to students who demonstrate a good record of achievement in mathematics and science, not all participants elect to pursue careers in technological or managerial fields. However, given the impact of technology on society, all gain from the experience whatever the future educational or career direction.

Programs offered through the Center for Pre-College Programs are possible because of an effective partnership. Federal agencies such as the National Science Foundation and the Department of Education encourage and support some programs. Private philanthropic organizations and the corporate sector represent the most important sources of assistance. New Jersey Institute of Technology, for its part, provides physical resources and personnel. Such a partnership is critical to the maintenance of pre-college programming. As a university, NJIT must meet its primary mission elements of instruction and research, allocating its limited financial resources toward that end.

It is a goal of the Center for Pre-College Programs to develop comprehensive sequential offerings for students from seventh through twelfth grades. The value of such a program to individual students, and to society, encourages all of us to pursue the realization of that goal with vigor.

Saul K Fenster



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Dr. Howard Kimmel*
Professor
Dept. of Chemical Engineering & Chemistry

*Directors of The Center for Pre-College Programs

NJIT

PROGRAM DIRECTORS

Upward Bound
Mr. William Freeman, Director

College Bound
Ms. Anne Wright, NJIT
Ms. Janet MacEachen, East Side H.S.
Mrs. Lillian Lago, Central H.S.

University High Integrated Calculus/Physics
Dr. William Savin

Urban Engineering
Dr. Howard Kimmel
Dr. Harold Deutschman

Mini-Courses: Urban Engineering
Dr. Harold Deutschman
Dr. Howard Kimmel

Science High School Laboratory Course
Dr. Howard Kimmel
Prof. Leon Landsman

Energy/Environment for Secondary School Teachers
Dr. Howard Kimmel

Project SEED
Dr. Joseph Bozzelli
Dr. Arthur Greenberg

Chemical Industry Minority Engineering Program (ChIME)
Dr. Reginald P.T. Tomkins

COLLEGE BOUND PROGRAMS NJIT AND CENTRAL HIGH SCHOOL

The **College Bound Program** is a cooperative program offered during the academic year by New Jersey Institute of Technology and Central High School. Central High School students are provided with academic support, tutoring, counseling and enriching social experiences. Students have access to NJIT facilities.

DATA

Audience Served: Newark

Number of Students Enrolled: Approximately 50

Academic Emphasis: English, Mathematics, and Science

Distinctive Characteristics of Program: College Bound serves as a college preparatory project for the students involved. Tutoring is offered at all grade levels and visits to college and career counseling are arranged for seniors.

Sponsor: The Florence and John Schumann Foundation

Time Frame: Central High's school year.

INTEGRATED CALCULUS-PHYSICS COURSE AT NJIT

This program was created as a special curriculum for Newark's University High School, an honors high school that enrolls high ability, highly motivated secondary school students in Newark. NJIT's specialized course stresses the development of good study habits as part of the overall learning process. College credit based on level of academic performance is available to participants.

DATA

Audience Served: Newark

Number of Students Enrolled: Approximately 15

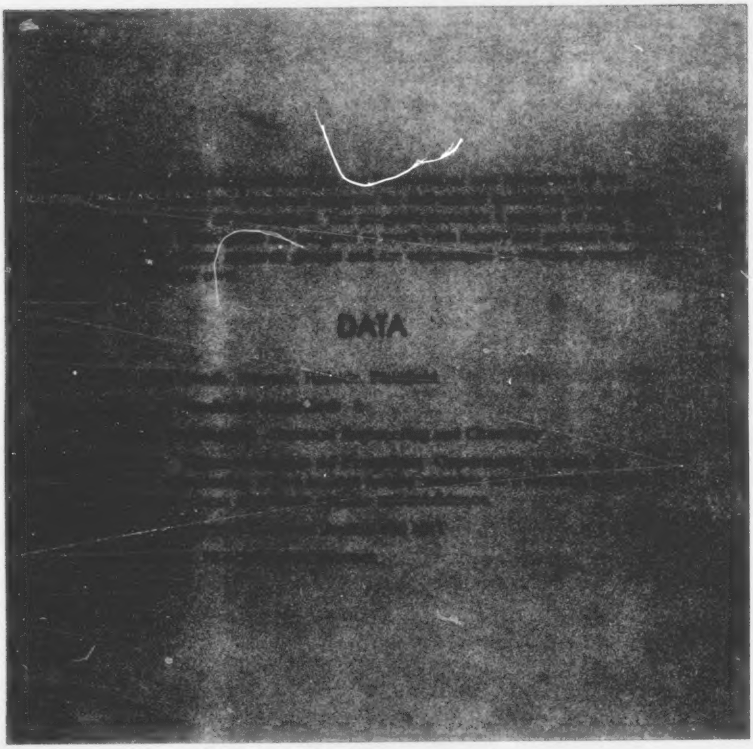
Academic Emphasis: Mathematics, Science

Distinctive Characteristics of Program: Laboratory sessions and tutoring by NJIT faculty and students provide an opportunity for individualized instruction. Each student receives a scientific calculator for use during the course.

Sponsors: Mobil Research & Development, Burroughs Corporation

Time Frame: Academic year

PROJECT SEED, CATALYST PROGRAM



DATA

13

UPWARD BOUND PROJECT

An academic year and summer program, **Upward Bound** is designed to help students develop basic skills necessary for success in high school and college. Much of what is accomplished during the academic year program relies on student progress during a summer preparation program. Based on results of tests administered at the end of the summer session, academic and study skills activities are scheduled for each student for the following academic year.

DATA

Audience Served: Newark

Number of Students Enrolled: 50

Academic Emphasis: Mathematics, Science, English, Environmental Studies.

Distinctive Characteristics of Program: All academic studies are reinforced with counseling and intensive tutoring in each subject. Students are involved in a wide array of social and cultural activities that include field trips, college visits, academic and sports competitions, and participation in science fairs.

Sponsor: U.S. Department of Health, Education and Welfare.

Time Frame: Academic year and six week summer session.

JUNIOR HIGH SCHOOL INTRODUCTION TO URBAN ENGINEERING

The objective of **Introduction to Urban Engineering** program is to introduce students to the excitement of science and engineering, with insight into the role of engineers and scientists as problem solvers. Emphasis is placed on developing techniques to solve urban problems. Guidance ensures that students are aware of requisite science and mathematics courses necessary to qualify for admission to college.

DATA

Audience Served: Largely Newark and East Orange

Number of Students Enrolled: 87

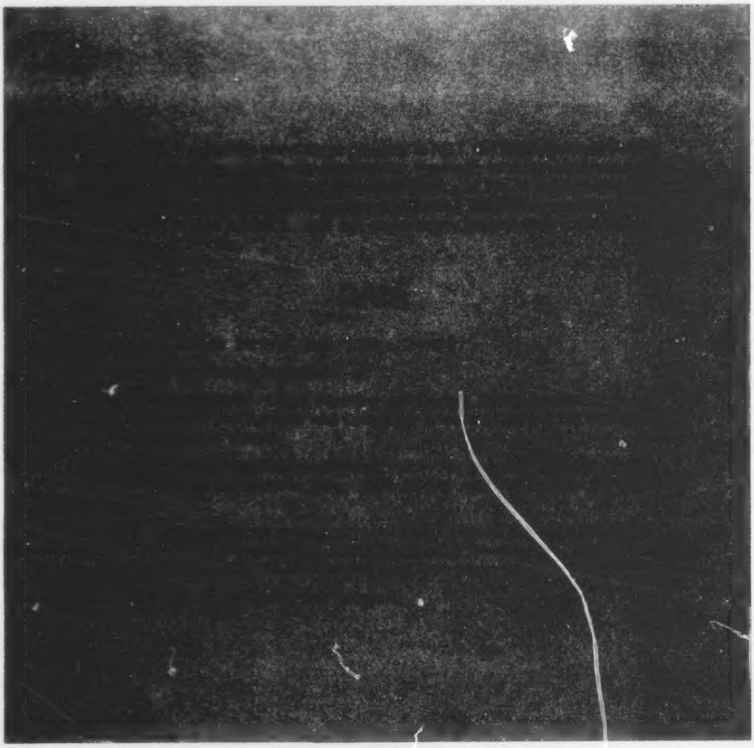
Academic Emphasis: Urban Planning, Transportation Engineering, Environmental Science and Energy.

Distinctive Characteristics of Program: The program includes special projects on which the students work as groups. They become urban planners for a group-created community in which they identify and eliminate existing problems related to urban living, transportation systems and the general environment.

Sponsors: National Science Foundation, Exxon Research & Development, Mobil Research & Development, Public Service Electric & Gas Co., Prudential, Bell Labs, New Jersey Bell, Hoffmann-La Roche.

Time Frame: Three week summer session.

HIGH SCHOOL URBAN ENGINEERING



RESEARCH APPRENTICESHIP PROGRAM FOR MINORITY HIGH SCHOOL STUDENTS

SATURDAY MINI-COURSES

Mini-Courses extending over two and three week periods are held Saturdays during the academic year for high school juniors and selected sophomores. Instruction in computer programming, computer applications and environmental/urban planning are among the offerings.

DATA

Audience Served: Newark and surrounding Municipalities.

Number of Students Enrolled: 400

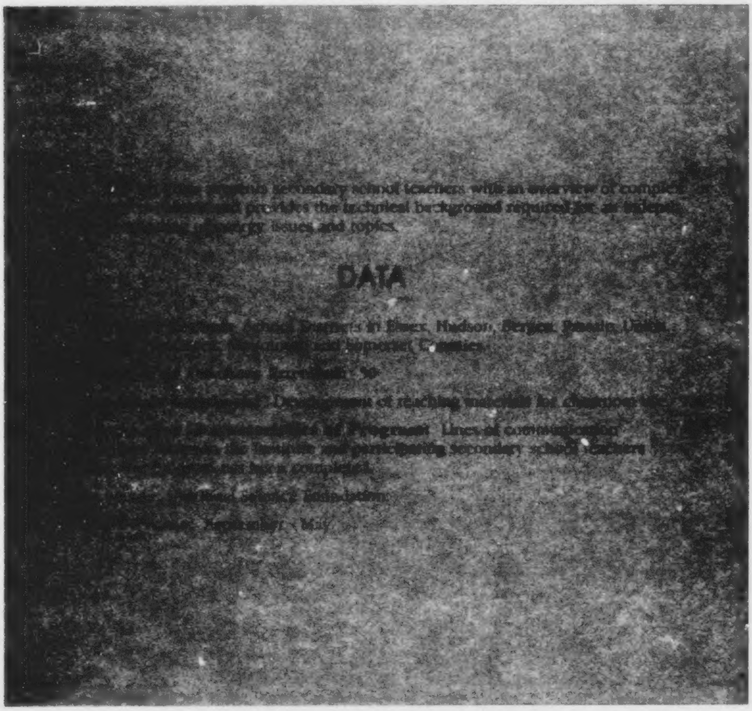
Academic Emphasis: As described above.

Distinctive Characteristics of Program: High percentage of minority students; self-motivation for increased knowledge.

Sponsor: Shelby Cullom Davis Foundation.

Time Frame: Saturdays, academic year.

ENERGY AND ENVIRONMENTAL TECHNOLOGY FOR SECONDARY SCHOOL TEACHERS



[illegible] program provides secondary school teachers with an overview of complex [illegible] and provides the technical background required for an indepth [illegible] of energy issues and topics.

DATA

[illegible] Public School Districts in Essex, Hudson, Bergen, Passaic, Union, [illegible] Monmouth and Somerset Counties.

[illegible] Enrolled: 50

[illegible]: Development of teaching materials for classroom use

[illegible] of Program: Lines of communication [illegible] the Institute and participating secondary school teachers [illegible] has been completed.

[illegible] National Science Foundation

[illegible] September - May

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ChIME WORKSHOP FOR HIGH SCHOOL STUDENTS

ENERGY EDUCATION WORKSHOPS

21

ENERGY CONVOCATION FOR GIFTED ELEMENTARY SCHOOL CHILDREN

This convocation allows gifted and talented children participating to work with professionals in the field of energy in a non-conventional setting.

DATA

Audience Served: Hudson County School Districts.

Number of Students Enrolled: 60

Academic Emphasis: Energy.

Distinctive Characteristics of Program: Professionals from industry, NJIT and other academic institutions meet with students on various energy issues and topics. The students have opportunities to do creative work in developing and proposing solutions to real-life problems.

Sponsor: Hudson County Schools.

Time Frame: Two day convocation, March.

1980-81 PRE-COLLEGE PROGRAMS

PROGRAM	AUDIENCE
College Bound	Central H.S. Newark
Integrated Calculus - Physics Course	University H.S. Newark
Science High School Laboratory Course	Science H.S. Newark
Project SEED - Catalyst Program	Newark, Hillside & Plainfield
Upward Bound Project	Newark High Schools
Junior High School Introduction to Urban Engineering	Newark & Regional N.J. & N.Y. Junior High Schools
(Senior) High School Urban Engineering	Newark & Regional N.J. & N.Y. High Schools
Research Apprenticeships, for Minority H.S. Students	Newark, Plainfield

TIME FRAME	SPONSORS
September - June	Florence & John Schumann Foundation
September - June	Mobil Research & Development, Burroughs Corporation
September - June	Visceglia Foundation NJIT
10 weeks Summer Session	American Chemical Society NJIT
September - June Six Week Summer Session	Department of Health, Education & Welfare
Three Week Summer Session	National Science Foundation Exxon, Bell Laboratories; The Prudential Foundation, Mobil R&D, Hoffmann-La Roche
Six Week Summer Session	National Science Foundation Exxon, The Prudential Foundation, Mobil R&D Public Service Electric & Gas Co., Hoffmann-La Roche
Calendar Year	National Science Foundation

1980-81 PRE-COLLEGE PROGRAMS

PROGRAM	**AUDIENCE**
Saturday Mini-Courses	Newark & Regional N.J. & N.Y. High Schools
Energy & Environmental Technology for Secondary School Teachers	Essex, Hudson, Bergen, Union, Morris, Monmouth, Middlesex, Passaic & Somerset County School Districts
WORKSHOPS	
Chemical Industry Minority Engineering Program Workshop for High School Students	Newark, Bayonne, Old Bridge, Plainfield, Elizabeth, Linden, Upper Montclair, South Amboy, Orange
Energy Education	Newark Irvington
Energy Convocation for Gifted Elementary School Students	Hudson County School Districts

TIME FRAME	SPONSORS
12 Saturdays During Academic Year	Shelby Cullom Davis Foundation
September - May	National Science Foundation
Four to five weeks, summer	Chemical Industry Council
February - May	NJIT & Newark and Irvington School Districts
March	Hudson County Schools

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PRE-COLLEGE PROGRAMS
AVERAGE PARTICIPATION STATISTICS

NAME OF PROGRAM		ENROLLED
College Bound Program		51
Integrated Physics-Calculus Course		22
Science High School Laboratory Course		14
Project SEED, Catalyst Program		3
Upward Bound Project		50
Junior H.S. Introduction to Urban Engineering		87
High School Urban Engineering		81
Research Apprenticeship for Minority H.S. Students		5
Saturday Mini-Courses		400
Energy & Environmental Technology for Secondary School Teachers		50
	Total	763

NAME OF WORKSHOP		ENROLLED
ChIME Workshop for H.S. Students		23
Energy Education		145
Energy Convocation for Gifted Elementary School Children		60
	Total	228

CONTINUING EDUCATION COURSES

16 Options – one-day programs on variety of topics		150
	Total	150

GRAND TOTAL 1141

ACKNOWLEDGEMENTS

The Center for Pre-College Programs gratefully acknowledges the assistance of sponsors and those friends of New Jersey Institute of Technology whose cooperation has contributed to the success of recent programs.

PROGRAM SPONSORS

American Chemical Society
Bell Laboratories
Burroughs Corporation
Chemical Industry Council
Exxon Research & Engineering Company
The Florence & John Schumann Foundation
Hoffmann-La Roche, Inc
Mobil Research & Development Corp
New Jersey Bell Telephone Company
The Prudential Foundation
Public Service Electric & Gas Company
Shelby Cullom Davis Foundation
Victoria Foundation, Inc
Vincent and Anna Visceglia Foundation

FIELD TRIPS/VISITS

ARRADCOM, Dover, N.J
Bell Laboratories, Murray Hill, N.J
Consolidated Edison, New York City
Exxon, Linden, N.J
Fairleigh Dickinson University
Hoffmann-La Roche, Nutley, N.J
N.J. Turnpike Authority, East Brunswick
New York University
Procter & Gamble, Staten Island, N.Y.
Stevens Institute of Technology
Trenton State College
Western Electric, Springfield, N.J.

CAREER GUIDANCE SEMINARS

Bendix Corporation
Burroughs Corporation
Ethicon, Inc
Exxon Research and Engineering
The Grad Partnership
New Jersey Bell Telephone Company
The Prudential Insurance Co. of America
Public Service Electric & Gas Company
Tri State Regional Planning Commission

Dr. Fenster. My appearance before this committee today is in marked contrast with the situation that confronted us in 1982. The administration's budget request for science education was restricted to maintaining the status quo for the fellowship programs. During the course of this past year there has been a growing recognition of the importance of the revitalized Federal role for science education.

This trend has been manifested in numerous legislative proposals, widespread media attention, and congressionally approved increases for science education funding at the NSF.

Finally, the fiscal 1984 administration request for science education not only increases the funding level but also expands the program in scope. The Committee on Science and Technology is to be congratulated on its role during the past year. Earlier this week the committee approved a major legislative proposal, H.R. 1310, Emergency Mathematics and Science Education Act. This bill will provide assistance for both precollege and postsecondary education institutions, and is an important first step in restoring the health of American science education.

You are to be applauded for your efforts in this very important legislation. Building upon this initiative I now urge the committee to take similar positive steps in approving a fiscal 1984 NSF authorization bill that adequately reflects the needs of the Nation in science education and is consistent with the critical nature of the problem.

I would like positively to comment on several aspects of the administration's fiscal 1984 budget request: A $39 million request for science and engineering education, including $19 million for graduate fellowships and $20 million for new precollege teacher improvement programs, and $3 million requested for undergraduate college research support to encourage involvement in research by undergraduates enrolled at predominantly undergraduate institutions.

In addition to these education functions of the NSF, there are proposed substantial increases in the research budget, particularly in the mathematical and physical sciences and engineering. The budget also calls for a new program of a Presidential young investigator's award and a major initiative to support research instrumentation needs. We are supportive of all these efforts and urge the Committee to approve these increased programs.

We are doubtful, however, that the levels of funding requested by the administration are adequate in terms of needs. We believe that funding levels on the order of $130 million, as recommended by this committee in H.R. 1310, are required to permit NSF programs to achieve their intended impact.

Furthermore, I feel that during these authorization hearings the committee should not lose sight of the NSF's mandate to support science education programs that are not emergency in nature as defined in H.R. 1310. NSF must look to the extended dimensions of the current problems.

Therefore, I urge this committee to authorize science education programs at the NSF that will provide continuity of support for its mandated educational function. H.R. 1310 together with a broad-based authorization for science education at NSF will serve as an important foundation for preventing further erosion in our Nation's science education effort.

As guidance for the Committee's efforts to determine actual needs, I would like the Committee to consider the suggestions contained in "Higher education's Agenda in Mathematics, Science and Technology Education." A copy of this document, Mr. Chairman, is attached to my testimony and I request that it be incorporated for the record.

Higher Education's Agenda represents the collective thinking of all sectors of the higher education community. I would urge the Committee to consider our recommendations for the following programs at the NSF: a program providing opportunities for teachers, young scholars and researchers through expanded graduate fellowships, new traineeships and faculty research awards, a program to upgrade and improve instructional programs at all levels, a program to upgrade instructional equipment and its utilization, and a program to strengthen educational research in science and mathematics.

We think that these programs should be an important part of any expanded NSF role in science education. There should be a new and expanded program of opportunities for teachers, young scholars and researchers through expanded fellowships, new traineeships research incentive awards, and faculty awards for summer study. These should increase the production of scientists, engineering faculty, researchers and science educators and to upgrade teaching faculty.

There are four programs we believe should be supported in this area: An expanded graduate fellowship program; a new traineeship program in science, technology and mathematics educators; a new faculty research incentive awards program; and a new program of faculty awards for summer study, sabbaticals and special research opportunities.

We propose a new program, also, to improve undergraduate instructional programs and to develop school and college materials for mathematics, science and technology education. Priority areas within that category would include: The restructuring of subject matter of science courses to reflect state-of-the-art technology and changing needs of undergraduates; applying teaching and learning research concepts to the development of mathematics, science and technology and instructional materials for schools and colleges. These two items would be priorities among the ones listed in the full testimony.

With respect to a program to upgrade undergraduate instructional equipment and its utilization, we propose a two-part program for the acquisition and installation of modern instructional equipment for use in teaching and training for teachers, and the sharing of science equipment among institutions regionally and between the academic and business sectors.

We further suggest that a balanced program is needed involving all Federal agencies that support research and related educational programs to make the acquisition of equipment and the renovation of laboratories an allowable component of research proposals.

With respect to precollege teacher training I would like to comment that in the past years NSF has conducted highly successful institutes that provided secondary school teachers with indepth scientific knowledge. These institutes have positively impacted on many thousands of teachers and, in turn, upon their students. Fiscal 1983 NSF Appropriations Act requires that an activity at the precollege level, primarily aimed at mathematics and science teacher training in the secondary schools be established. The outcome of this plan is still somewhat uncertain, but I do want to acknowledge in a very positive way the role that the NSF has played in the past and will continue to play in fiscal 1983 in precollege teacher training programs.

This committee recently called for the establishment of summer institutes and workshops for precollege teachers to be supported by both the Department of Education and the NSF. We regard this dual support system as a positive step forward.

With respect to a program to strengthen educational research in science and mathematics, the NSF, in consultation with the National Institute of Education and the cognitive, engineering, and information science programs in the research directorates, should be authorized to conduct research and development activities in the following areas: Cognitive science applied to math and science learning, instructional uses of computers and other information technology, and the increased understanding of higher order academic skills related to future learning and work.

The program support should focus on the use of research and development for improvement of school and college instruction in math, science, and technology.

I would like to address a couple of other items briefly, Mr. Chairman. There has been some discussion with respect to the matching funds component. Many State initiatives now provide for matching funds from non-State resources and in the Federal area, matching funds for non-Federal resources. I would say that on the basis of our institutional experience this is a fine principle, articulating the private and public sectors.

I should say we as an institution have benefited from this principle of matching funds but there nevertheless is a caution that ought to be advanced. Some institutions with respect to matching are placed at a distinct disadvantage in their competition for the matching funds. For example, some institutions may suffer a geographic disadvantage. They may not be in proximity of corporations or private sources of matching funds. Some institutions may be too small to mount any significant fund raising or development effort.

With respect to the possibility of an institution raising funds from nonpublic sources, clearly an independent institution may enjoy an advantage inasmuch as most of its funds would be nonpublic funds.

With respect to the issue of those institutions better known than others, the prestigious institution may be at a distinct advantage in obtaining matching funds.

Finally, and I suppose this is a comment very specific to my institution and other institutions which are perhaps midway through a fund-raising campaign or which have completed a fund-raising campaign, they may be at a disadvantage with respect to timing in any ability to match inasmuch as they have to go back to the very same corporations and foundations which may have supported a past effort, go back to them again with the likely response that they will have to wait for their turn which may be several years down the road. They may, in fact, lose an opportunity to obtain matching funds whether it would be on a State matching fund basis or a Federal matching fund basis.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Fenster follows:]

Statement by

Saul K. Fenster

President

New Jersey Institute of Technology

on

The Fiscal Year 1984 National Science Foundation

Budget Authorizations

on Behalf of

American Association of State Colleges and Universities

and

American Association of Colleges for Teacher Education
American Association of Community and Junior Colleges
American Council on Education
American Educational Research Association
Association of Affiliated College and University Offices
Association of American Colleges
Association of American Universities
Association of Catholic Colleges and Universities
Association of Jesuit Colleges and Universities
Association of Urban Universities
California State University
Council of Graduate Schools in the United States
Council of Independent Colleges
National Association for Equal Opportunity in Higher Education
National Association of College and University Business Officers
National Association of Independent Colleges and Universities
National Association of Schools and Colleges of the United Methodist Church
National Association of State Universities and Land-Grant Colleges
State University of New York

Before the
Committee on Science and Technology
U.S. House of Representatives

February 25, 1983

My name is Saul Fenster and I am President of The New Jersey Institute of Technology in Newark, New Jersey, a position I have held for the last five years. Prior to assuming the presidency of New Jersey Institute of Technology I was Chairman of the Department of Mechanical Engineering, Associate Dean of Engineering and Provost at Farleigh Dickinson University. I received a BME from City University of New York, an MS from Columbia University, and a Ph.D. from the University of Michigan. I am a member of the American Association for the Advancement of Science, American Society for Mechanical Engineering and American Society for Engineering Education.

I am pleased to have the opportunity to once again appear before this Committee to testify on the FY 1984 National Science Foundation Authorization Bill, with particular emphasis on science and engineering education.

I represent 354 member institutions of the American Association of State Colleges and Universities and am currently Vice Chairman of its Committee on Science and Technology. I am also speaking on behalf of the 20 associations who participated in the development of "Higher Education's Agenda in Science, Mathematics and Technology Education."

With a combined enrollment of close to 2 1/2 million students, the 354 state colleges and universities of AASCU enroll one out of five of all baccalaureates degree students in the country. Our institutions play a major role in our nation's science effort. Many students who ultimately pursue advanced degrees in scientific and technical fields receive their basic undergraduate training at our institutions. A large portion of the nation's future elementary and secondary school science and mathematics teachers are educated at AASCU colleges and universities. These teachers must be able to communicate the knowledge and skills that will enable our youth to live in an increasingly complex and technology-dependent society. AASCU institutions award close to one-fifth of the B.S. degrees in engineering annually and over one-third of the B.S. degreees in computer and information sciences.

Current Crisis in Science Education

This committee is well aware of the current national crisis in science, mathematics and technology education. During the course of your recent hearing on H.R. 1310, testimony was introduced that pointed to the decay in our scientific educational system:

- documented declines in student achievement in mathematics and sciences. Average science and mathematics scores on standardized college entrance tests have been dropping steadily for 20 years;
- a serious shortage of qualified mathematics and science teachers. During the 1970's the number of secondary

school mathematic teachers being trained declined 77 percent; science teachers being trained declined 65 percent. Some 50 percent of newly employed teachers nationwide are currently uncertified and unqualified to teach mathematics and science. This situation is exacerbated by the rapid departure of trained classroom teachers for better paying jobs in industry;

- at least 2,000 vacant faculty positions in university engineering departments. These vacancies have resulted in enrollment limits which, in turn, impede the training of adequate number of B.S. engineers;
- the obsolescence of much of the instrumentation and equipment used in college and university laboratories has been well documented;
- tens of thousands of technician openings are going begging even as the national rate of unemployment approaches 11 percent. The Congressional Budget Office projects that new technologies will make three million more jobs obsolete by the end of this century;
- secondary students are taking fewer courses in math and science than in years past, and fewer courses are being offered. Half of all U.S. high school students take no mathematics after the tenth grade, while in other industralized nations, particularly Japan and Germany, increasing emphasis is being placed on science and mathematics education;

- since 1972 there has been a 54 percent decline in the number of Ph.D.'s awarded in engineering yearly to U.S. nationals, while Ph.D.'s in engineering awarded to foreign students have more than doubled; and
- Japan, one of our primary competitors in the world marketplace, produces twice as many engineers as we do even though their population base is half ours. From 1970 to 1977 the number of engineers per 1,000 workers increased by 48 percent in Japan and decreased by nine percent in the U.S.

There is a bipartisan recognition of this growing crisis. President Reagan, in a message to the 1982 National Academy of Sciences Convocation on Science and Mathematics in the Schools, declared; "The problems today in elementary and secondary school science mathematics education are serious -- serious enough to comprise America's future ability to develop and advance our traditional industrial base to compete in international market places." The Special Task Force on Long Term Economic Policy of the House Democratic Caucus observed in the report Rebuilding the Road to Opportunity: "in the future, a well-educated, well-trained workforce will be essential to sustained economic growth ... the future will be won with brainpower... The research we must undertake to produce new technologies requires talent -- yet we are not graduating sufficient numbers of scientists, engineers and technicians."

Although there is now general agreement on the dimensions of the problem, there is no consensus on the solution. Constructive actions at the institutional, local, state, and national levels are necessary to forestall a further deterioration.

THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

I strongly believe that the National Science Foundation (NSF) must play a leading role in restoring the health of American science education.

When the National Science Foundation was established in 1950, it was authorized and directed to "initiate and support basic scientific research and programs ... and science education programs at all levels." The educational mandate of the National Science Foundation has been an integral part of our nation's scientific establishment since that time.

We believe that the reasons for the Foundation's charter in science and engineering education remain as valid today as they did in 1950 and that adequate funding for science and engineering education must be restored.

The NSF's support of science and engineering education has been crucial to my institution. Currently NJIT has a large and successful Center for Pre-College Programs. The aim of these programs is to provide disadvantaged students -- many of them from minority groups -- with the technical skills necessary to pursue careers in the sciences and engineering. It is a demanding program, but 92 percent of our participants successfully complete it and go on to college.

The NSF originally funded support for this program and it served 245 students. With this in operation, we were able to go to the corporate and industrial community for additional support. Now the program serves 1,000 students. The government seed money stimulated an investment by private industry that was 2 1/2 times the original federal support. Having worked with the private sector to build this program. I know that the federal support was the crucial catalyst in attracting industrial funds.

FY 1984 NSF BUDGET AUTHORIZATION

My appearance before this Committee today is in marked contrast to the situation that confronted me in 1982. The Administration's budget request for science education was restricted to maintaining the status quo for the fellowship programs. During the course of this past year there has been a growing recognition of the importance of a revitalized Federal role for science education. This trend has been manifested in numerous legislative proposals, widespread media attention and Congressionally approved increases for science education funding at the National Science Foundation. Finally, the FY 1984 Administration request for science education not only increases the funding level but also expands the program scope.

The Committee on Science and Technology is to be congratulated on its role during the past year. Earlier this week, the Committee approved a major legislative proposal, H.R. 1310, Emergency Mathematics and Science Education Act. This $425 bill will provide assistance to both precollege and postsecondary institutions and is an important first step in restoring the health of American science education. Chairman Fuqua and the other members of the Committee are to be applauded for their efforts in moving this legislation forward early in this Congressional session and for their spirit of cooperation in working to resolve their differences with the Education and Labor Committee.

Building upon this initiative in H.R. 1310, I now urge the Committee to take similar positive steps in approving a FY 1984 National Science Foundation Authorization bill that adequately reflects the needs of this nation in science education and is consistent with the critical nature of the problem.

I would like to positively comment on several aspects of the Administration's FY 1984 budget request:

- $39 million requested for science and engineering education, including $19 million for graduate fellowships plus $20 million for new precollege teacher improvement programs;
- $3 million requested for undergraduate college research support to encourage involvement in research by undergraduates enrolled at predominantly undergraduate institutions.

In addition, to these education functions the National Science Foundation proposes substantial increases in its research budget, particularly in the mathematical and physical sciences and engineering. The budget also calls for a new program of Presidential Young Investigators Award and a major initiative to support research instrumentation needs. We are supportive of all these efforts and urge the Committee to approve these increases and programs.

The Administration's request for science education funding for FY 1984 request is an important foundation for this Committee to build upon in setting its own budget priorities. We are doubtful, however, that the levels of funding requested by the Administration are adequate in terms of actual needs. We believe that funding levels on the order of $130 million, as recommended by this Committee for H.R. 1310, are required to permit NSF programs to achieve their intended impact.

Furthermore, I feel that during these authorization hearings the Committee should not lose sight of the National Science Foundation's mandate to support science education programs that are not "emergency" in nature, as defined in H.R. 1310. These compelling long range needs bear upon the capability of higher education to ensure the production of new knowledge and skilled manpower, necessary for our long range economic welfare and military security. Clearly, there is a continuum in the decline of science education capacities. H.R. 1310 treats one aspect of this continuum but the National Science Foundation must look to the extended dimensions of the current problems. Therefore, I urge this Committee to authorize science education programs at the National Science Foundation that will provide continuity of support for its mandated educational function. H.R. 1310 together with a broad based authorization for science education at NSF will serve as an important foundation for preventing further erosions in our nation's science education efforts.

As guidance for the Committee's efforts to determine actual needs, I would like the Committee to consider the suggestions contained in "Higher Education's Agenda in Mathematics, Science and Technology Education." A copy of this document is attached to my testimony and I request that it be incorporated in the record. Higher Education's Agenda represents the collective thinking of all sectors of the higher education community. It contains specific programmatic suggestions for Federal support of science education.

I would urge the Committee to consider our recommendations for the following programs at the National Science Foundation:

- a program providing opportunities for teachers, young scholars and researchers through expanded graduate fellowships, new traineeships and faculty research awards;
- a program to upgrade and improve instructional programs at all levels;
- a program to upgrade instructional equipment and its utilization; and
- A program to strengthen educational research in science and mathematics

We think that these programs should be an important part of any expanded National Science Foundation role in science education.

A Program of Opportunities for Teachers, Young Scholars and Researchers through Expanded Fellowships, New Traineeships, Research Incentive Awards, and Faculty Awards for Summer Study

We propose the establishment of a series of new and expanded programs to provide fellowships, traineeships, summer study support, research incentive awards, and faculty renewal awards to increase the production of scientists, engineering faculty, researchers and science educators, and to upgrade teaching faculty.

Four programs should be supported in this area:

(1) An expanded Graduate Fellowship Program. The structure and effectiveness of the NSF Graduate Fellowship Program, once a premier symbol of the nation's commitment to excellence, has diminished steadily over the years. The NSF fellowship program should be expanded by increasing the number of awards and the amount of the stipend.

(2) A new Traineeship Program for science, technology and mathematics educators. Trainees would be selected by participating departments, schools and institutions from among individuals with demonstrated potential to excel as science, technology and mathematics educators at elementary/secondary and undergraduate levels. Institutions receiving traineeships would gather education specialists and faculty from departments of science,

mathematics and technology to create for the trainee a new or improved quality program for preparing the next generation of science educators.

(3) A new Young Faculty Research Incentive Awards Program. The challenges facing young faculty who seek to establish their first research programs are almost overwhelming. A program offering stable support (averaging $50,000 per year per award) to assist them in starting academic research careers would help to sustain the quality and flow of individuals into key fields of science, mathematics, engineering and technology. This is similar to the Presidential Young Investigators Award Program proposed by the Administration.

(4) A new program of Faculty Awards for summer study, sabbaticals, and special research opportunities. This program would provide awards for summer support to permit currently employed faculty to take advantage of upgrading opportunities; and a program for experienced faculty for six- to twelve-month periods at salary equivalent to current levels to: (a) permit revitalization, and experience with new research techniques and advanced research discoveries for those who have been isolated from research institutions and

centers for six or more years; and (b) provide for intensive development of teaching techniques and materials in problem areas. Awards should be provided on a competitive basis to individuals whose institutions certify that the applicant's principal function is undergraduate teaching in a science-related discipline.

A Program to Upgrade and Improve Instructional Programs in Mathematics, Science and Technology at All Levels

Continuing demands are placed on science educators to keep pace with evolving technological innovations. Updated instructional materials are needed to enhance student motivation and to advance the lagging state of science learning. The need for new instructional materials is particularly acute at the undergraduate level for both general students and engineering majors.

We propose a new program to improve undergraduate instructional programs and develop school and college materials for mathematics, science and technology education.

Priority areas include:

(1) restructuring subject matter science courses to reflect state-of-the-art technology and the changing needs of undergraduate;

(2) applying teaching and learning research concepts to the development of mathematics, science and technology instructional materials for schools and colleges; and

(3) stimulating collaborative educational institution/industry efforts in the development of improved programs

for schools and colleges.

A Program to Upgrade Undergraduate Instructional Equipment and Its Utilization

The outmoded condition of the instructional equipment in the nation's colleges and universities is well-documented. The absence of state-of-the-art equipment and facilities has immediate consequences in the preparation of today's students, and far-reaching implications for the nation's ability to remain scientifically and technologically competitive.

We propose a two-part program for:

(1) acquisition and installation of modern instructional equipment for use in teaching and training for teaching; and

(2) sharing science equipment among institutions regionally and between the academic and business sectors.

We further suggest that a balanced program is needed involving all federal agencies that support research and related education programs to make the acquisition of equipment and renovation of laboratories an allowable component of research proposals:

A Programs for Precollege Teacher Training

In addition, I would like to comment on the National Science Foundation's role in teacher training. In past years, the National Science Foundation has conducted highly successful institutes that provided secondary schools teachers with indepth scientific knowledge. These institutes have positively impacted on many thousands of teachers and, in turn, upon their students. The FY 1983 NSF Appropriations Act (P.L. 97-272) requires that an activity at the precollege level, primarily aimed at mathematics and science teacher training in the secondary schools be established. The outcome of this plan is still some uncertain but I do want to acknowledge in a very positive way the role that the National Science Foundation has played in the past, and will continue to play in FY 1983, in precollege teacher training programs.

This Committee recently called for the establishment of summer institutes and workshops for precollege teachers to be supported by both the Department of Education and the National Science Foundation. We regard this dual support system as a positive step forward.

The National Science Foundation institutes draw upon the highly technical and scientific knowledge that is necessary to upgrade the subject matter content of the teacher. As a Federal science agency with broad ties to academic sciences and engineering, NSF has a unique responsibility to foster the involvement of professional scientists and engineers in the improvement of education in the sciences, mathematics and technology at all levels. This is particularly important because of the rapid advances of these fields.

However, it is equally important that the teacher know how to effectively communicate in a classroom setting this newly acquired scientific knowledge. The Department of Education has a role to play in seeing that this communication takes place. We also feel that the Department of Education supported institutes will provide an important link between institutions of higher education and local schools and school districts. We think that this link is an essential ingredient in improving the science and math that is taught in the precollege classroom. The establishment of precollege teacher training activities at both the Department of Education and the National Science Foundation will help us to reach our goal -- an improved system of precollege math and science education.

A Program to Strengthen Educational Research in Science and Mathematics

The National Science Foundation, in consultation with the National Institute of Education (NIE) and the cognitive, engineering, and information science programs in the research directorates, should be authorized to conduct research and development activities in the following areas: cognitive science applied to math and science learning, the instructional uses of computers and other information technologies, and the increased understanding of higher order academic skills related to future learning and work. Program support should focus on the use of research and development for improvement of school and college instruction in mathematics, science, and technology.

NSF and NIE should work together and draw upon their particular strengths. NSF, with the ties to practicing scientists, engineers and basic research directorates, will be in a position to work in the areas of computers and information technologies, and to apply basic research in human cognition to learning and instructional program development activities. NIE has the associations with education policy makers and practicing educators in schools and colleges, and has the capacity to merge teacher and learning research with the substantive instructional areas of mathematics and science.

Both agencies should consult on the development of R & D agendas, the selection of peer reviewers (to assure high quality work), and the dissemination of R & D results.

....

I appreciate the opportunity you have given me to appear before this Committee and will be happy to answer any of your questions.

HIGHER EDUCATION'S AGENDA IN
MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION

Background

America's productivity, economic welfare and national defense are threatened by the growing crisis in our education system. Awareness of this problem manifested itself during the 97th Congress in numerous legislative proposals, reports of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, the proliferation of private sector programs, and widespread media attention.

The dimensions of the problem are multifaceted and permeate our educational system from the precollege level to the community college, the undergraduate classrooms and the graduate universities. There is considerable evidence of the decline of our scientific educational system:

- documented declines in student achievement in mathematics and sciences. Average science and mathematics scores on standardized college entrance tests have been dropping steadily for 20 years;

- a serious shortage of qualified mathematics and science teachers. During the 1970's the number of secondary school mathematics teachers being trained declined 77 percent; science teachers being trained declined 65 percent. Some 50 percent of newly employed teachers nationwide are currently uncertified and unqualified to teach mathematics and science. This situation is exacerbated by the rapid departure of trained classroom teachers for better paying jobs in industry;

- at least 2,000 vacant faculty positions in university engineering departments. These vacancies have resulted in enrollment limits which, in turn, impede the training of adequate numbers of B.S. engineers;

- the obsolescence of much of the instrumentation and equipment used in college and university laboratories has been well documented;

- tens of thousands of technician openings are going begging even as the national rate of unemployment approaches 11 percent. The Congressional Budget Office projects that new technologies will make 3 million more jobs obsolete by the end of this century;

- secondary students are taking fewer courses in math and science than in years past, and fewer courses are being offered. Half of all U.S. high school students take no mathematics after the tenth grade, while in other industrialized nations, particularly Japan and Germany, increasing emphasis is being placed on science and mathematics education;

- since 1972 there has been a 54 percent decline in the number of Ph.D.'s awarded in engineering yearly to U.S. nationals, while Ph.D.'s in engineering awarded to foreign students have more than doubled; and

- Japan, one of our primary competitors in the world marketplace, produces twice as many engineers as we do even though their population base is half ours. From 1970 to 1977 the number of engineers per 1,000 workers increased by 48 percent in Japan and decreased by 9 percent in the U.S.

There is bipartisan recognition of this growing crisis. President Reagan, in a message to the 1982 National Academy of Sciences Convocation on Science and Mathematics in the Schools, declared: "The problems today in elementary and secondary school science and mathematics education are serious -- serious enough to compromise America's future ability to develop and advance our traditional industrial base to compete in international marketplaces." The Special Task Force on Long Term Economic Policy of the House Democratic Caucus observed in its report Rebuilding the Road to Opportunity: "in the future, a well-educated, well-trained workforce will be essential to sustained economic growth . . . the future will be won with brainpower . . . The research we must undertake to produce new technologies requires talent -- yet we are not graduating sufficient numbers of scientists, engineers and technicians."

The Federal Role

Although there is now general agreement on the dimensions of the problem, there is no consensus on the solution. The higher education community views the current crisis with alarm. Constructive actions at the institutional, local, state, and national levels are necessary to forestall a further deterioration.

We believe the federal government must play a central role in providing leadership and support for a variety of initiatives outlined in the following pages. Sustained federal investment is required because the problems are national in scope and because failure to resolve them would have grave implications for our national well-being and defense capability. These investments will maximize the return on scarce federal resources, encourage local and individual initiatives, minimize federal control of these efforts, and provide incentives for collaboration among all sectors.

America's postsecondary institutions -- two-year, four-year, and graduate -- all have a major role to play in restoring our economic health and bolstering our national defense. Their resources should be directed to the most critical problems that beset the science education system so that adequate numbers of qualified mathematics and science school teachers will be trained; education for technology and science-related careers will be provided; the proper research environment, experience and tools to train the next generation of scientists, engineers and researchers will be encouraged; and research to improve instruction and the educational uses of information technology will be supported. With such steps students will be sufficiently science-literate to live in an increasingly technological world and have the opportunity to prepare for careers in the sciences; and currently employed teachers, engineers, scientists and researchers will have opportunities to upgrade their skills.

Thus we urge the 98th Congress to enact major legislation that will enable colleges and universities to further fulfill their mission as a vital force in solving the current science, mathematics, and technology education crisis. The higher education community recognizes the interrelationship among all levels of education in resolving the crisis and supports the efforts of the precollege sector to solve their own unique and compelling problems. However, this paper attempts only to address the crisis from the perspectives of higher education.

Proposed Federal Program

The higher education community -- collectively listed at the end of this paper -- supports the establishment of five new programs to be administered by the Department of Education and the National Science Foundation. These programs represent the top priorities of the higher education community regarding science, mathematics and technology education. Each is an essential component of the total effort needed in this area.

For the Department of Education, we propose two programs: a $200 million program for teacher training initiatives to improve science, mathematics and technology education, and a $25 million program to strengthen educational research in these areas.

For the National Science Foundation, we propose three programs: a $100 million program providing opportunities for teachers, young scholars and researchers through expanded graduate fellowships, new traineeships and faculty research awards; a $50 million program to upgrade and improve instructional programs on all levels; and a $200 million program to upgrade instructional equipment and its utilization.

The total $575 million dollar federal investment proposed provides a significant number and variety of new awards to individuals, schools, and colleges. Coupled with local, state and private sector initiatives, these programs will make a substantial contribution toward the revitalization of the science education in the nation.

In embarking on this new federal effort in sciences, math and technology education we must acknowledge the importance of a sustained national commitment to basic research. Without quality research programs, the education enterprise will wither. Our proposal for new federal support of science education should be viewed as an integral part of this commitment. Both research and education are necessary for the economic vitality and defense strength of the U.S. Neither should be funded at the expense of the other.

Title: A Program for Teacher Training Initiatives to Improve Science, Mathematics and Technology Education

Agency:	Department of Education
Authorization:	$200 million
Target:	3,000 grants at up to $200,000 each to schools and colleges

We propose the establishment of a grant program for schools, colleges and universities to be administered by the Department of Education with proposals to be evaluated through a peer review process involving consultation with NSF to identify field readers. The purpose of these grants is to encourage the linkage between colleges and universities and public and private elementary and secondary schools in the improvement of science education. Grants would allow maximum institutional flexibility to be responsive to local needs, and would be awarded according to plans developed by the recipient institution in collaboration with one or more public or private schools or school districts and other appropriate agencies or councils. Priority activities might include, for example:

(1) summer institutes and workshops and a parallel program of inservice education, conducted by higher education institutions across all states and regions to provide practicing teachers and supervisors with up-to-date science and mathematics information and pedagogical concepts;

(2) projects to enhance the capacity of schools and colleges to meet the professional needs of both new and practicing teachers including faculty development activities; and

(3) support for exemplary state, local and institutional efforts to attract, retain and motivate teachers to pursue careers in precollege mathematics and science education, as well as identification of teacher training projects providing nationally significant examples of campus-based inservice, school site staff development, and the integration of substantive knowledge in mathematics and the sciences with effective teaching strategies, and the dissemination of information about these programs.

Title: A Program to Strengthen Educational Research in Mathematics/Science and Technology Education

Agency:	National Institute of Education, in consultation with the National Science Foundation
Authorization:	$25 million
Target:	New grant competitions for specific research yielding 10 major programmatic awards, and up to 200 individual research grants.

Research on student learning and school and college instruction in math, science, and technology education (particularly focused on secondary schools) is an essential resource for other federal, state and local programs for improving math and science education.

We propose a new program to strengthen teaching and learning research through grants focused on the identification of successful instruction and the application of cognitive research to improved instructional programs. The program will support large scale research competitions dealing with:

(1) research on thinking, teaching and learning related to instruction in math, science and technology;

(2) research on the uses of modern instructional technologies; the status, means of assessment, and selection of instructional software and other mathematics, science and technology education materials;

(3) research on local, state and institutional policies enhancing or inhibiting the recruitment, retention and professional development of school and college math and science faculties; and

(4) research on school, institution and state needs and operations as they relate to the development and support of remedial programs at all levels of education.

Title: A Program of Opportunities for Teachers, Young Scholars and Researchers through Expanded Fellowships, New Traineeships, Research Incentive Awards, and Faculty Awards for Summer Study

Agency:	National Science Foundation
Authorization:	$100 million
Target:	$15 million to expand existing graduate fellowships and to create 600 new graduate fellowships; $15 million for new institutional traineeship programs; $50 million for 1,000 new faculty research incentive awards; $20 million for faculty awards for summer study sabbaticals and special research opportunities.

We propose the establishment of a series of new and expanded programs to provide fellowships, traineeships, summer study support, research incentive awards, and faculty renewal awards to increase the production of scientists, engineering faculty, researchers and science educators, and to upgrade teaching faculty.

Four programs should be supported in this area:

(1) An expanded Graduate Fellowship Program. The structure and effectiveness of the NSF Graduate Fellowship Program, once a premier symbol of the nation's commitment to excellence, has diminished steadily over the years. The NSF fellowship program should be expanded by increasing the number of awards and the amount of the stipend. To achieve this, we propose at least doubling the amount of money available for these fellowships (from $15 million to $30 million) and increasing by approximately one-third both the number and size of the current awards (from 1,400 to 2,000 and at least $15,000 rather than $10,900 per award).

(2) A new $15 million Traineeship Program for science, technology and mathematics educators. Awards of up to $150,000 would be made to colleges and universities. Trainees would be selected by participating departments, schools and institutions from among individuals with demonstrated potential to excel as science, technology and mathematics educators at elementary/secondary and undergraduate levels. Institutions receiving traineeships would gather education specialists and faculty from departments of science, mathematics and technology to create for the trainee a new or improved quality program for preparing the next generation of science educators.

(3) A new $50 million Young Faculty Research Incentive Awards Program. The challenges facing young faculty who seek to establish their first research programs are almost overwhelming. A program offering stable support (averaging $50,000 per year per

award) to assist them in starting academic research careers would help to sustain the quality and flow of individuals into key fields of science, mathematics, engineering and technology. 1,000 awards would be authorized to average $50,000 per year.

(4) A new $20 million program of Faculty Awards for summer study, sabbaticals, and special research opportunities. This program would provide 3,000 awards at $5,000 each for summer support to permit currently employed faculty to take advantage of upgrading opportunities; and a $5 million program for experienced faculty for six- to twelve-month periods at salary equivalent to current levels to: (a) permit revitalization, and experience with new research techniques and advanced research discoveries for those who have been isolated from research institutions and centers for six or more years; and (b) provide for intensive development of teaching techniques and materials in problem areas. A total of $20 million authorized in this area will provide awards on a competitive basis to individuals whose institutions certify that the applicant's principal function is undergraduate teaching in a science-related discipline.

Title: A Program to Upgrade and Improve Instructional Programs in Mathematics, Science and Technology at All Levels

Agency:	National Science Foundation
Authorization:	$50 million
Target:	1,000 instructional improvement projects at up to $200,000 each.

Continuing demands are placed on science educators to keep pace with evolving technological innovations. Updated instructional materials are needed to enhance student motivation and to advance the lagging state of science learning. The need for new instructional materials is particularly acute at the undergraduate level for both general students and science and engineering majors.

We propose a new program to improve undergraduate instructional programs and develop school and college materials for mathematics, science and technology education.

Priority areas include:

(1) restructuring subject matter science courses to reflect state-of-the-art technology and the changing needs of undergraduates;

(2) applying teaching and learning research concepts to the development of mathematics, science and technology instructional materials for schools and colleges; and

(3) stimulating collaborative educational institution/industry efforts in the development of improved programs for schools and colleges.

Title: A Program to Upgrade Undergraduate Instructional Equipment and Its Utilization

Agency:	National Science Foundation
Authorization:	$200 million
Target:	Grants to colleges and universities

The outmoded condition of the instructional equipment in the nation's colleges and universities is well-documented. The absence of state-of-the-art equipment and facilities has immediate consequences in the preparation of today's students, and farreaching implications for the nation's ability to remain scientifically and technologically competitive.

We propose a two-part program for:

(1) acquisition and installation of modern instructional equipment for use in teaching and training for teaching; and

(2) sharing science equipment among institutions regionally and between the academic and business sectors.

We further suggest that a balanced program is needed involving all federal agencies that support research and related education programs to make the acquisition of equipment and renovation of laboratories an allowable component of research proposals.

* * * * * * * * * * * * * *

N. B.: Existing laws and recent legislative proposals have attempted to utilize the mechanism of tax incentives to encourage a corporate response to the science education crisis. We regard these proposals as one aspect of the total effort needed to resolve the urgent problems faced by higher education institutions. These proposals are uniquely well-suited to bringing private sector resources into play. Since this paper addresses only the necessary role of the federal government in the direct provision of support, we have omitted references to these tax incentive proposals.

This proposal is submitted on behalf of the following organizations:

American Association of Colleges for Teacher Education
American Association of Community and Junior Colleges
American Association of State Colleges and Universities
American Council on Education
American Educational Research Association
Association of Affiliated College and University Offices
Association of American Colleges
Association of American Universities
Association of Catholic Colleges and Universities
Association of Jesuit Colleges and Universities
Association of Urban Universities
California State University
Council of Graduate Schools in the United States
Council of Independent Colleges
National Association for Equal Opportunity in Higher Education
National Association of College and University Business Officers
National Association of Independent Colleges and Universities
National Association of Schools and Colleges of the United Methodist Church
National Association of State Universities and Land-Grant Colleges
State University of New York

Mr. **Walgren**. Thank you, Dr. Fenster, and we certainly appreciate those reservations about the matching fund. It is difficult to know how to surmount those problems.

Mr. Bateman.

Mr. **Bateman**. Mr. Chairman, I wish that our time were such that we could have heard you earlier and had more opporutnity for an extended dialog.

I have returned to an indication of thinking that you may have heard earlier. In looking over your higher educational agenda for science and mathematics and in your prepared statements, I see, again, the dismal statistics on the pool of qualified teachers in science and math, the number of vacancies that exist, the number of people who are leaving the field.

Isn't it one of those things that is self-evident that less people would leave it if those who were qualified, competent, dedicated, and skilled were compensated better and, therefore, had a more economically viable future by staying in it?

If that is self-evident, isn't it somehow strange that in all of the accumulated statements around, positions and recommendations, I have not seen a word that says, "Let's pay these people who are most needed, most talented and most dedicated and most likely to be recruited to the private sector, more than we are paying them."

Could you offer me some reactions to that and whether or not we are likely to see any movement along those lines to add the incentive that has got to be done? We can't draft people into classrooms to teach science and mathematics.

Dr. **Fenster**. Sometimes some of the most obvious points are not made as succintly as you have just made them, Mr. Bateman.

I would certainly applaud your statement. We have found that notwithstanding the enormous gap between salaries paid to young Ph. D. engineers in industry and in the academic world, many are motivated to go into teaching even at economic disadvantage. They like the research environment providing there is adequate research equipment.

They like the notion of dealing with students and their peers in a given field and they are willing to suffer some economic disadvantage. Sometimes the gap goes beyond even that tolerance level.

We have found that where we are able to supplement their salaries or guarantee them summer research, we can attract faculty members. We are able to recruit where there are some supplements of that kind, not necessarily salary supplement, during the regular academic year and where there is some guarantee to the faculty member in the recruiting process that those summer supplements would continue on for several years.

Recently, the Exxon Corp., announced and began the implementation of a young faculty salary supplement program which we were fortunate in being participants in. We have used successfully those salary supplements to encourage young faculty members either to come to the institution or to remain in the institution and have, in fact, incorporated the Exxon program grant as part of our recruiting advertising and have done it successfully.

So, I think that I would underscore and give support to the notion that part of this problem in attracting good teachers and in retaining good teachers has got to do with making teaching an economically competitive and attractive profession; yes, sir.

Mr. **Bateman**. Well, would it follow from that that perhaps this Congress should address it by allocating some of the funds proposed to be expended to enhance the education in science and math to economic incentives for retention of the most proficient of those presently in the system?

We can't make young people want to take it. We are not going to get them to want to take it if they are not adequately instructed and if we don't keep the best. Things are likely to get worse, not better, and yet I don't see that the one thing that seems to be the problem or as I say, so self-evident and which would have the most immediate positive implications, at least for the near term, even being addressed.

Dr. **Fenster**. I believe within the agenda there are some proposed programs that perhaps do go to that issue, Mr. Bateman. I would have to identify the specific program, but I think there are some elements that go to young researchers, programs of opportunities for teachers, young scholars and researchers, faculty awards for summer study and so on, which would go to the issue of some economic incentives to stay in the field.

Mr. **Bateman**. Well, they are there but I think they are cast, as I read them anyway, and of course I've had to read them very hurriedly, more in the context of intellectual climate that is provided which I think is very important and it is vital to anyone who is going to remain a good, effective, enthusiastic teacher.

But you know the intellectual climate in which you can feed your children or educate your children will, I think, go begging because in private industry, in research and in large corporate laboratories and other areas, you will find that stimulation and professional satisfaction and compensation.

Dr. **Fenster**. I quite agree.

Dr. **Fuller**. Mr. Bateman, I think you will find that if you are going to talk about the appropriate role of the Federal Government in helping here, that if you are going to try to supplement salaries of teachers at the precollege and at the postsecondary level, that we may be beyond any likelihood of success.

The appropriate Federal role may well be an enhancement of status, a recognition of the contribution, whether it's from a precollege science and math teacher or at the postsecondary level. What they are doing is important. Finding ways to reward it, finding ways to supplement that environment, that is the task of meeting outside salary competition is the task of the institutions, the States, the localities. The Federal Government should certainly be highlighting the problem and, we hope, getting some movement from these other areas.

I think the need here is that kind of enhancement and recognition which certainly is appropriate to the Federal role and is within the range of possible Federal appropriation.

Mr. **Bateman**. With the Chair's indulgence, I will not carry any longer than to say, could we perhaps also have a common case in advancing the notion that where States, Government, and public funds, are directed toward our educational system at all levels, we ought to break this pattern of equal distribution as opposed to distributing the money on the basis of merit and the recognized superiority. The former situation diffuses whatever increases in appropriations come your way on some sort of, I think, somewhat misguided policy of equality. Perhaps equality of unfairness.

Dr. **Fuller**. I think at institutions like those I deal with you find that recognition is already there in the salary structures. If we want to go out and find someone in computer science we expect to pay a good deal more than we have to pay when you are looking for someone in English history. That reality is there.

There are, unfortunately, legislative and contractual restrictions particularly in the publicly supported structure which make this impossible, and that is part of the problem.

Mr. **Bateman**. Concerns are much more specifically addressed to the public sector and most especially to the secondary school system.

Dr. **Fenster**. Mr. Bateman, while not being impossible, necessarily, in the public sector, it is certainly more difficult. We do have merit components to our salary structure system, but not to any degree that I would like to see.

Mr. **Bateman**. Thank you.

Mr. **Walgren**. Thank you, Mr. Bateman.

Mr. Brown.

Mr. **Brown**. Thank you, Mr. Chairman. It is not easy to find issues to differ with you gentlemen on because in a sense you are supporting a thrust which this committee has taken for some time, and we appreciate your contribution to the record of this hearing on those matters.

I know you have commented on the committee's concern with the health of undergraduate education including the role of the community colleges. And the chairman of the subcommittee, I know, has been a leader in trying to maintain that kind of a focus. I am sure that you will continue to do so.

If I may raise just one question. It has to do with the role of your institutions as links in a network, you might say. We are putting a great deal of emphasis on university-industry relations.

We are putting a great deal of emphasis upon the responsibility of institutions of higher learning to show concern and take responsibilities for the improvement of education at the lower levels to maintain the flow of persons motivated and capable in the science and mathematical-related fields.

In looking at the list of the institutions which you gentlemen represent, I note several that have achieved recognition for their involvement in the community, and I would just like to ask you to comment if you feel that you are doing as much as can be expected or attempting to improve your role in both of these areas.

That is, within your own communities and regions you are, in effect, a node of prestige. Some of the larger national universities, research institutions, would almost appear sometimes to feel that they are too good to get involved in the communities around them and in their region. What we would like to encourage is a sense that every institution is a part of their community and has a responsibility to play.

If you and your institutions, to provide an example of how to do that effectively, I think you could put the large research institutions to shame and we might want to lend even more encouragement to that sort of a thing.

Could you comment on that?

Dr. **Fuller**. I appreciate the comments, Mr. Brown. I don't think we have done as much as we should. I know that every one of the colleges I work with has programs reaching out to their local school districts and some of the others in their region.

We have found that some of those efforts of outreach have not been warmly received in recent years. I am not sure what the problem has been.

In fact, some of our colleges have found it difficult to sustain their role in training teachers for the elementary and secondary schools because our emphasis on subject matter expertise, on high quality of the knowledge of the subject the student is going to teach is sometimes at war with some of the requirements that are set for teacher certification.

We think that climate is changing. We certainly have an obligation to do more. I think there was a very distinguished history of partnership in the late fifties and early sixties when there was a larger national concern. In those days college and university faculty were working on the improvement of elementary and secondary curricula and were seen as partners.

We would like to see that repeated much more than it has been. I think part of the fault is on our side and part of it is on the side of those who might join that partnership or share it with us. I think you may find that it is changing a good deal. There was a conference last week that Ernie Boyer of the Carnegie Foundation sponsored trying to talk specifically about the ways in which higher education institutions and elementary and secondary institutions can work more closely together.

That is a topic that I hear about at every higher education meeting I go to now and I think you will find a lot more happening of that sort. That will be to the good.

Dr. **Fenster**. Mr. Brown, this community interaction of which you speak is very much a mission element within our institution which, among other things, defines itself as an urban university. This is at least one reason that we have taken so seriously the entire precollege effort having just this last year extended the precollege effort to the seventh grade.

Previously it had started at the ninth grade. We have an enrollment of some 1,000 youngsters in some dozen precollege programs as I said earlier with a very high college going rate and several hundred secondary school teachers involved in various institutes and upgrading programs throughout the year.

This past year, in fact, we created a computer center through cooperation with the private sector dedicated to the precollege program. So with regard to the precollege activities we regard them as very much within this area but beyond that we work with local school districts and local school boards to help those boards make the most effective use of their own material and human resources.

For example, we have worked with school boards to improve their own management information systems and inventory control systems to, if you will, incorporate technology transfer in their own school districts to have a more contemporary management operation, and, to the extent that we can, to help them also improve in the curricular area.

Other institutions are also working very seriously with the local schools in the curriculum area.

We would like to have a network, frankly, of several thousand universities and colleges participating in a similar way with local schools and local school districts. I think the cumulative impact of that on the nature and quality of precollege education particularly in science, mathematics and technology would be enormous.

Mr. **Brown**. Well, in thinking through this problem in my own mind, it seems to me that we have a period in which there is rapid change taking place in society and we are really trying to grasp what our national goals, our national character and our national resources are, and in that kind of a period it is much more important that we have stronger linkages between all of the institutions of society in order that we can more effectively interact in setting these goals and making these changes that are taking place. If we don't, then we set up terrible tensions in the society.

As a Congress, as representatives of the people, we are concerned about the whole of the society, not just whether we produce more Nobel laureates or something of that sort, but is the whole society benefiting from what we are doing.

This is where we sometimes do not give full credence and importance to the work which institutions such as those you represent, the role you play in the society.

Thank you, Mr. Chairman. That is all that I have.

Mr. **Walgren**. Thank you, Mr. Brown.

Well, on behalf of the subcommittee, I would like to express our appreciation for your testimony and for your staying with us throughout the morning. We appreciate that very much. Thank you.

Dr. **Fenster**. Thank you very much, Mr. Chairman.

Dr. **Fuller**. We appreciate the opportunity.

Mr. **Walgren**. At this point I would like to insert in the record several items that relates to the subject of today's hearings.

[Whereupon, at 1:30 p.m., the subcommittee was adjourned.]

A Participating Organization of the
AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE
1776 Massachusetts Avenue, N.W.
Washington, D.C. 20036

202-223-6995
202-467-4325

March 21, 1983

RECEIVED
MAR [illegible] 1983
COMMITTEE ON SCIENCE
AND TECHNOLOGY

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
2321 Rayburn House Office Building
U.S. House of Representatives
Washington, DC 20515

Dear Representative Fuqua:

Over the past 18 months, the Scientific Manpower Commission has become increasingly concerned about the quality and quantity of precollege science and math education. Both reflect ultimately on the quantity and quality of scientists and engineers to be produced in the future, as well as the general electorate which must be willing to support scientists and engineers for the betterment of the nation. Increasingly, this concern has come to be focused on the problem of the shortage of qualified science and math teachers for secondary classrooms. However, there is a problem of accurate data. Beyond the surveys carried out with its own funds by the National Science Teachers Association (NSTA) and one survey made by Iowa State University of state science supervisors, the essential background data required for making informed choices in solving these problems has not been available. While we believe that the NSTA has done an excellent job in outlining at least some of the parameters of the problem, we do not feel that the collection of needed data should be either the burden of that association or its responsibility. The implications of the problem are nationwide; they pervade American society.

Over the past several months, Congressional committees have become aware of and concerned about these problems, and an unusually large number of bills have been introduced in both Houses which seek to apply funds to ameliorate this serious situation. Policymakers in the Congress, in state legislatures, in school districts, on school boards, and in state departments of education should not be asked to make policy without adequate, dependable and continuing data on both the nature and extent of the shortage of qualified teachers. The facts provided through the NSTA surveys are well known to you and becoming more widely known to others who are concerned. However, the problem will not be solved overnight and continuing adjustments in programs will be needed during the recovery process.

At its meeting on March 15, the Scientific Manpower Commission passed unanimously the following resolution:

"The Scientific Manpower Commission strongly urges that the National Science Foundation support the collection and maintenance on a continuing basis of data on the manpower characteristics of math and science teachers in elementary and secondary schools in the United States."

Knowing that the budget process is lengthy, and the time for starting to resolve these problems is long past, I have been asked by the Commission to transmit this resolution to you and to urge your consideration.

Sincerely yours,

Ray A. Williamson

Ray A. Williamson
President

American Anthropological Association
American Association for the Advancement of Science
American Astronomical Society
American Chemical Society
American Geological Institute
American Geophysical Union
American Institute of Biological Sciences
American Institute of Chemists
American Institute of Physics
American Meteorological Society
American Psychological Association
Federation of American Societies for
Experimental Biology
Society for Industrial and Applied Mathematics

Association of American Publishers, Inc

aap

2005 Massachusetts Avenue N.W.
Washington D.C. 20036
Telephone 202 232 3335

March 21, 1983

Hon. Doug Walgren, Chairman
Subcommittee on Science, Research and
Technology
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is the testimony of the Association of American Publishers on renewal of the authorization of the National Science Foundation. We ask that this statement be included in the printed hearing record.

Sincerely,

Roy H. Millenson, Director
Education & Library Affairs

Enclosures

Association of American Publishers, Inc.

aap

2005 Massachusetts Avenue, N.W.
Washington, D.C. 20036
Telephone 202 232-3335

Testimony of Association of American Publishers
on
National Science Foundation Authorization
Subcommittee on Science, Research, and Technology
House Committee on Science and Technology

March, 1983

The Association of American Publishers (AAP) is the general association of book publishers in the United States. It comprises Professional and Scholarly Publishing; College; International; Direct Marketing/Book Club; School and General Trade divisions. Our some 300 member publishing houses produce the vast majority of general trade, educational, reference, professional and religious books published in this country and found in the nation's libraries as well as considerable related audio-visual materials.

The tradition of including prohibitions against undue Federal influence over education programs is firmly engrained in statute.

In 1958, Congress included in the National Defense Education Act (NDEA), enacted that year, a provision stipulating that "nothing contained in this Act shall be construed to authorize any department, agency, officer or employee of the United States to exercise any direction, supervision, or control over the curriculum, program of instruction, administration, or personnel of any educational institution or school system."

And, in 1970, Congress carried this language over into the General Education Provisions Act (GEPA), the law governing all HEW education programs. It was again spelled out in fuller detail in 1979 in the Department of Education Organization Act, Sec. 103(b) of which states:

> No provision of a program administered by the Secretary or by any other officer of the Department shall be construed to authorize the Secretary or any such officer to exercise any direction, supervision, or control over the curriculum, program of instruction, administration, or personnel of any educational institution, school, or school system, over any accrediting agency or association, or over the selection or content of library resources, textbooks, or other instructional materials by any educational institution or school system, except to the extent authorized by law.

Most recently, in 1983, the 97th Congress included the following section in the Job Training Partnership Act (JTPA):

/more/

Prohibition Against Federal Control of Education

> Sec. 145. No provision of this Act shall be construed to authorize any department, agency, officer, or employee of the United States to exercise any direction, supervision, or control over the curriculum, program of instruction, administration, or personnel of any educational institution, school, or school system, or over the selection of library resources, textbooks, or other printed or published instructional materials by any educational institution or school system.

We urge that a similar provision be included in the enabling legislation for the National Science Foundation, the National Science Foundation Act of 1950, as amended. Such a provision would be consistent with well-established Congressional policy. It would provide insurance against any possible suspicion that currently expanding NSF science and engineering programs might unduly encroach upon state, local and university prerogatives and would be an effective instrument in helping NSF minimize such embarassments of the type suffered during the 1970's as a result of the MACOS project.

Association of American Publishers, Inc.

aap

2005 Massachusetts Avenue, N.W.
Washington, D.C. 20036
Telephone 202 232 3335

Testimony of Association of American Publishers
on
National Science Foundation Authorization
Subcommittee on Science, Research, and Technology
House Committee on Science and Technology

March, 1983

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NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

April 28, 1983

Honorable Don Fuqua
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

The HUD-Independent Agencies Appropriations Subcommittee fiscal year 1983 conference report required the National Science Foundation to provide a plan which would propose programs for precollege science and engineering education activities during fiscal year 1983. The Fiscal Year 1983 Appropriations Act provided an additional $15 million for these programs. Enclosed is a copy of that plan which has been approved by both of the HUD-Independent Agencies Appropriations Subcommittees.

The National Science Board will be reviewing program guidelines based on this plan at their May meeting; after that meeting, more detailed program descriptions will be broadly distributed. Please let me know if you have any further questions or need additional information.

Sincerely,

Ray Bye

Raymond Bye, Jr.
Head
Congressional Liaison

Enclosure

RECEIVED
APR 29 1983
COMMITTEE ON SCIENCE
AND TECHNOLOGY

4/11/83

A PLAN FOR NATIONAL SCIENCE FOUNDATION SUPPORT OF PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION

SUMMARY

The Administration proposes activities, to be implemented by the National Science Foundation (NSF), that address the declining quality of U.S. precollege science and mathematics education. This decline, which began a decade ago, must be stopped and reversed because the U.S. economic and defense competitivenesss depends heavily on an adequate supply of scientists, engineers and a technically skilled workforce. A strong precollege education in science and mathematics is required to provide the necessary skills.

The plan of activities is designed to meet several conditions. It recognizes that:

1. There are distinct roles for the Federal, state and local governments, and the private sector. The Federal government must assume a leadership and catalytic role, rather than dictate national solutions to local needs.

2. The two principal Federal agencies responsible for science and mathematics education, the National Science Foundation and the Department of Education, have very different statutory authorities and capabilities. The NSF plan described here reflects this difference.

3. The teacher, teaching materials, and techniques are central to the motivation and learning of the students. The planned activities seek to enhance the motivation and competence of the teachers and to facilitate the delivery of knowledge to students.

The proposed plan has two major components: the development of materials and the provision of teacher incentives. These components are discussed in terms of the FY 1983 budget. These activities are planned to continue in FY 1984.

a. Materials Development

The National Science Foundation will support the development of exemplary materials and models for the continuing improvement of teachers. Research and analyses will be conducted and the results continuously fed into the materials development effort so that these materials reflect the best practical experience and ideas, as well as scientific knowledge that can be brought to bear on the processes and content of precollege science and mathematics teaching. The potential of technologies (e.g., computers, television programs) to improve the delivery of materials and the learning processes will be explored. Model programs will be conducted to evaluate and improve the materials developed.

No less than $12 million of the NSF 1983 budget will be devoted to materials development. These materials will be made widely known and available to local educational authorities.

b. Teacher Incentives

Presidential Awards for Teaching Excellence will be given to outstanding science and mathematics teachers. This national recognition of science and mathematics teachers is designed to improve the image and status of mathematics and science teachers. The awards will be administered by NSF in cooperation and with the participation of DoED.

Teacher Honors Workshops will recognize and honor the top quality science and mathematics teachers, provide them with updated knowledge, practical experience or skills, and require that they spread this knowledge to their fellow teachers. These workshops will also be used to provide feedback on, and evaluation of, new teaching materials. Feedback from the workshop participants will be used to analyze science education.

No more than $3 million of the NSF 1983 budget will be used for teacher incentive and recognition.

BACKGROUND

This paper presents the Administration's proposed activities to be implemented by NSF in science and mathematics education. These activities aim to increase the quality of precollege student knowledge in science and mathematics.

School systems throughout the U.S. with strong and dynamic instruction in mathematics and science are vital to the U.S. economy and our Nation's long-term technological leadership. Well educated students are essential to provide a continuing supply of technical personnel needed by a U.S. economy increasingly dependent upon high technology.

The 1970's saw a serious erosion in the quality of U.S. scientific and technological education at all levels. Schools and colleges relaxed requirements for courses in the sciences and mathematics. Academic standards generally deteriorated with emphasis frequently shifted to courses of study lacking a sound disciplinary base. This trend was reflected in the NSF's science education program.

NSF, by its enabling legislation of 1950 and subsequent amendments in 1959, 1965, and 1972, was given major Federal responsibility for scientific research and education in the sciences. The NSF's science education program was substantially strengthened under President Eisenhower in the 1950s, but subsequently underwent a deterioration in the 1970's that paralleled that of the education system in general. The consensus on the importance of NSF's science education program dissipated, leading to disagreement among Congressional committees and within Administrations regarding the role and purpose of the program. This resulted in decreased budgets, loss of program focus, and a proliferation of small, socially directed activities.

The U.S. Office of Education, and later the Department of Education, during this time, was concerned mostly with issues of equity, such as programs for the handicapped, underprivileged, student aid, etc., and capacity building such as construction support. The Department of Education did support educational R&D but this support was also related to equity questions, or was in the nature of national data collection and analysis. Very little effort at the Department of Education was historically directed at the content of science and technology at any level of education.

FEDERAL ROLE

The activities proposed for NSF are consistent with the Administration's view of the proper Federal role in education.

The Administration assumes that:

- An adequate educated population requires strong precollege science and mathematics instruction.
- This requires attention and action by all sectors including state and local governments and industry.
- Local autonomy is a fundamental characteristic of the U.S. educational system. The Federal Government should not interfere with, or dictate to local authorities the design, planning, or operation of education programs. It should act only when a clear responsibility exists.
- In those specific areas where a clear responsibility exists, the Federal Government's role should be to provide the necessary leadership to address a national problem, and also stimulate and catalyze efforts in other sectors.
- Actions by the Federal Government are indicated when:
  - the problem is of a national nature;
  - these actions would provide large public benefits, but by their nature do not present opportunity for economic return to private interests (e.g., data collection and analysis of national data, research and development activities);
  - the actions should but cannot be replicated throughout the states otherwise.
- Federal actions should be targeted at specific, well identified sources of problems. These actions should be aimed at those areas where the benefits of Federal efforts accrue to wide segments of the population.

AGENCY ROLES

Assignment of responsibility for Federal action in the area of science education should be based on:

- statutory authority;
- capability and capacity of the agency based on authority, experience, public support, and support of the involved communities.

NSF and the Department of Education have distinctly different character when examined in light of these two criteria.

National Science Foundation

Statutory Authority

Section 3(a) of the National Science Foundation Act of 1950 states that "the Foundation is authorized and directed:"

- "to initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels in the mathematical, physical, medical, biological, engineering, social, and other sciences, by making contracts or other arrangements (including grants, loans, and other forms of assistance) to support such scientific and educational activities and to appraise the impact of research upon industrial development and upon the general welfare;"
- "to award, as provided in Section 10, scholarships and graduate fellowships in the mathematical, physical, medical, biological, engineering, social, and other sciences;...."
- "to foster and support the development and use of computer and other scientific methods and technologies, primarily for research and education in the sciences."

Section 3(d) also states that "The Board and Director shall recommend and encourage the pursuit of national policies for the promotion of basic research and education in the sciences." (underlines added)

Capability and Capacity

NSF has some basic characteristics which define the capability and capacity of the agency:

- a relatively small science granting agency staffed by persons with academic/scientific backgrounds; NSF does not conduct in-house research or education programs;
- awards based on competitive peer review, whose primary criterion is the scientific/science educational merit of the proposed ideas and activities;
- strong ties with the academic scientific and engineering community and science teaching profession;
- identification and support of innovative projects which typically are generated through proposals by scientific and technical experts (rather than by NSF).

A clear relationship and compatibility with these characteristics should be a primary consideration in the assignment of Federal responsibility in science and mathematics education to NSF. These strengths should be utilized to greatest advantage. In turn, programs which do not correspond to these characteristics would not only have lesser potential for success, but also weaken the agency's major strengths.

Department of Education

Statutory authority

The enabling legislation of the Department of Education defines a very broad mission, covering responsibilities for all levels of education. However, the legislation prescribes precisely the intended beneficiaries, recipients, funding mechanisms and eligible activities.

Capability and Capacity

Characteristics of the Department of Education which are significant in connection with Federal responsibility for science and mathematics education include:

- a large agency, staffed extensively by persons trained in the fields of education, with history of both funds allocation on uniform, national scale, and educational research at lower education levels;
- concern for equal educational opportunity, with special targeting of issues and groups (e.g., vocational education, bilingual education, disadvantaged groups);
- a variety of functions, ranging from grants-in-aid, to data gathering and dissemination, to national institutional capacity building such as construction of facilities;
- predominant use of formula grants to states and local agencies rather than competitive grants;
- wide contact with state and local educational agencies and colleges of education.

ADMINISTRATION'S EARLY INITIATIVES

Consistent with the definitions of appropriate Federal and agency roles in science and mathematics education, the Administration reviewed the state of the Nation's science and mathematics education and the Federal effort, and:

- Determined the need for Federal leadership in improving the quality of science and mathematics education.
- Recognized the fragmentation of NSF science education programs which prevented achievement of a significant national impact.
- Appointed the Department of Education's National Commission on Excellence in Education (a component of which is directed at science education) to make recommendations "....to the Nation and to the Secretary of Education to promote excellence in public and private schools, colleges, and universities."
- Appointed the National Science Board Commission to study the problems at the precollege level and "....define a national agenda for improving mathematics and science education in this country."

The Administration also has proposed several initiatives as part of a measured plan to reverse the decline in the quality of science and mathematics instruction in the Nation's schools.

- At the university level a new program of support for young science and engineering faculty has been included in the NSF budget. This is aimed at attracting highly qualified, young scientists and engineers to university positions, relieving faculty shortages and assuring high quality university education for future scientists and engineers.

- At the precollege level, Presidentially-directed activities are planned at both the NSF and the Department of Education focused on the supply of science and mathematics teachers and the quality of their teaching:
    - In 1983, NSF is budgeted at $15 million to conduct two programs aimed at teacher improvement, one updating the materials, skills, and knowledge needed by existing teachers, the other, a program to recognize and reward teachers who have done outstanding work. The budget request for these efforts is increased for 1984.
    - In 1984, the Department of Education has proposed funding in the amount of $50 million for block grants to the states to increase the number of qualified science and mathematics teachers. The program will provide one year scholarships to persons holding college degrees to enable them to return to school to become qualified to teach science and mathematics.

Independent actions have been taken also by state and local governments, such as pay supplements for science and mathematics teachers. Private industry, scientific and science education groups have made strong public statements of concern and some are increasing their efforts to address those aspects of the problem most closely related to their needs.

PROPOSED PLAN FOR NSF

The Administration's plan for the NSF precollege science and mathematics role in assuring an adequate technically trained workforce, scientific community, and technically functional society is based on these considerations:

- immediate problems and long-term needs for science and mathematics education;
- appropriate Federal and Agency roles;
- primary responsibility at state and local levels;
- need for active and sustained involvement of private sector;
- central role of teachers and teaching materials and techniques in student motivation and learning.

The Administration's Plan for NSF:

- is a measured approach to the clearest and most immediate aspect of the problem --the quality of precollege teaching;
- recognizes the need to undergird scientific and technological training with materials development support;
- includes mechanisms for identification and understanding of problems in precollege science and mathematics teaching.

The plan also coordinates the efforts and utilizes the strengths of the primarily responsible Federal agencies by proper assignment of roles.

National Science Foundation 1983 Precollege Science and Mathematics Activities

1983 Budget
($ in millions)

Materials Development	12
Teacher Incentives	3

Considerable evidence exists that precollege science and mathematics education is inadequate to meet the growing national needs for scientific and technical skills in the workforce.

Numerous studies have pointed to the decline in the quality of science and mathematics education in recent years. These studies have indicated that the precollege level in general, and the quality of precollege teachers and teaching in particular, is the most obvious and immediate source of the problem.

In addition, there is some indication of a decline in performance in science and mathematics of the top quartile of students. This raises questions for America's future health and long-term leadership in technology.

The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, was established to analyze and assess this problem and to make recommendations for its resolution. The NSF science and mathematics education plan for 1983 is based on preliminary Commission reports and findings of national studies and evaluations. It is also consistent with the proper Federal role, and NSF responsibilities and strengths. The plan focuses on the precollege level and is organized around two distinct components:

Development of Materials and Models

- The deteriorating quality of precollege science and mathematics teachers and their instruction is clear. There is a need for exemplary materials and models for the continuing professional development of teachers and the improvement of their instruction. These materials and models should reflect the best practical knowledge, experience and ideas as well as scientific knowledge that can be brought to bear on the processes and content of science and mathematics teaching. They should be based on a thorough understanding of conditions and needs in precollege science education.

Teacher Incentives

- Teaching characterized by low status and salary. There is a pressing need to recognize and nurture the skills of good mathematics and science teachers and to emphasize the significance of their contributions to education and the Nation, as one mechanism of attracting and retaining teachers in these critical skill areas.

Because of the importance and complex nature of precollege science education, care must be taken that NSF activities be of high quality and continuing relevance to national needs. Therefore, continuing input from a broad cross-section of the scientific/science and mathematics education community is essential to:

- advise the Director of NSF and the National Science Board on policies and directions the NSF program should follow;
- identify changing national needs in science and mathematics education;
- review the progress of the program in reaching its long-term goals;
- provide oversight on program procedures;
- provide guidance on revisions to program guidelines.

For these purposes, a Precollege Science and Mathematics Education Advisory Committee will be appointed. The Committee would consist of outstanding individuals recognized as knowledgeable about and experienced in U.S. precollege science and mathematics education, including representatives of local school districts. Prior to the establishment of this group, the NSF will consult broadly with similar types of individuals to review initial program guidelines.

Materials Development ($12 million in FY 1983)

The development of useful materials for teachers and students must be based on a thorough understanding of the conditions and needs of science and mathematics education. For this reason, research and analyses will be initiated to better understand the science and mathematics educational system, and how people teach and learn these subjects most effectively. The research activities by nature are applied and will make use of information on cognitive processes resulting from basic research on this subject (e.g., research sponsored by the Behavioral and Neural Sciences Division of NSF).

A focus here will be on monitoring and evaluating this information, the changes in scientific and technical knowledge, and the relationship of this knowledge to what is taught in the schools. An effort will be made to evaluate and use data collected by organizations with primary data collection responsibilities (e.g., National Center for Educational Statistics and NSF's Science Resources Studies). Evaluation of the impact of NSF science and mathematics education programs will also be included.

New mechanisms and materials will be produced for raising and sustaining the quality of precollege science teaching. Projects will be supported on a nationally competitive basis to:

- create models and demonstrations of innovative training programs focused on scientific and technical content, or new technologies for use in teaching, to provide continuing education for science and mathematics teachers;

- develop materials, audio and visual aids, computer programs, software, and systems for science teachers to use in improving their instruction.

Projects will include design, development and testing of materials, as necessary, operation of prototype programs for teachers, and evaluation of utility and impact of approach. An area of emphasis will be to develop and test applications of the new technologies to precollege science and mathematics education.

The principal products of materials development activities will be better, more effective approaches to teacher training and better tools for teachers and students to use in their classrooms and laboratories. Materials with multiple benefits; e.g., video materials suitable for both public broadcasting as well as classroom use will be included. Although the NSF does not attempt to be strongly prescriptive regarding the nature of projects, anticipated approaches include:

Materials

- better presentations of basic single concepts; e.g., molecular structure, wave motion;
- new techniques to improve student and teacher understanding and productivity, computer simulations of laboratory experiments, modeling, graphing;
- new topics, technology developments, science applications;
- approaches intended not only to provide science instruction, but also to make it more interesting and attractive to younger students.

Demonstrations

- projects structurally designed for individual schools, single school districts, states, regions, or nation-wide;
- national projects based on telecommunications techniques;
- single discipline and multidiscipline projects;
- refresher courses and new topics;
- use of computers and telecommunications in science and mathematics teaching.

The Foundation will require specific products from each development project; e.g., materials, software, descriptive program guides, etc., and where appropriate plans for commercial publication and distribution. Procedures will be developed to assure NSF supported products are available for utilization nationally in local teacher training delivery projects. NSF will consider future mechanisms for making such materials available to local users.

Support criteria will emphasize the participation of a combination of top scientific and teaching talent, and will encourage the appropriate participation of industry. Careful attention will be paid to procedures for assuring the effectiveness of training, such as examinations at the end of programs and the awarding of regular college credit or suitable alternatives recognition of concrete achievement.

It is expected that most proposals will be submitted by colleges and universities, but other institutions with education missions will be equally considered. Appropriate participation and collaboration among practicing teachers, scientists, science educators and officials of state and local education agencies will be a principal consideration for award. In addition, participation and contributions from the private sector, such as the involvement of industrial scientists, will be highly favored in agency evaluation of proposals.

Teacher Incentives ($3 million in FY 1983)

The teacher incentives activities focus on the unique problem of motivating, recognizing and bringing up to date science and mathematics teachers who are among the best the profession has to offer. This complements the materials and teacher training model development activity whose ultimate target population is the precollege science and mathematics teacher profession in general. Teacher incentives include Presidential Awards for Science and Mathematics Teaching Excellence and Teacher Honors Workshops.

The Presidential Awards for Science and Mathematics Teaching Excellence will provide highly visible recognition to approximately 100 outstanding teachers annually (about half in mathematics and half in science). The teachers will be selected nationally with at least one teacher from each state and other jurisdictions such as Puerto Rico and the District of Columbia. They will be presented with a certificate of excellence at an appropriate ceremony. An award of $5,000 will be made to each teacher's school to supplement, and not replace, other resources for use in improving its science or mathematics program, under the direction of the awardee teacher.

The importance of this program was emphasized in a recent radio message by the President when he said, "And we're also beginning a new program, one I intend to participate in myself, to honor some of America's best science and mathematics teachers. They are a true national resource."

The program will be administered by the NSF in coordination with the Department of Education, and with the assistance of a national professional scientific organization. The latter, under contract from NSF, will carry out the identification, nomination, and selection procedures for the awardees, and related necessary activities. The NSF will make the final selections and together with DoED confer the awards. Efforts will be made to obtain the participation and contributions of the private sector such as industrial companies, civic clubs, and local chapters of scientific societies.

The Teacher Honors Workshops activity accomplishes three purposes within the area of precollege science and mathematics teaching development:

-- recognizes and honors top quality teachers;

-- provides these top quality teachers with updating in current science, and mathematics; recent rapid advances in the sciences and technology make it necessary to update the technical knowledge of even the best teachers;

-- obtains for future planning purposes analyses of science education from the unique perspective of the best classroom teachers.

Grants will go to colleges and universities and other institutions with precollege science and mathematics teaching capability to develop, then operate programs of professional improvement for selected precollege teachers. Participation and contributions by industry will be strongly encouraged. Practical experience and demonstrated excellence in the design and delivery of precollege science and mathematics teaching will be emphasized and is strongly encouraged.

Activities consist of:

- identification and selection of science and mathematics teachers of demonstrated high quality and performance; certificates of honor, appropriate publicity, etc. will assure recognition and prestige for the selected;
- development of conference materials;
- workshops that provide specialized training and practical experiences in important areas of science and technology for the participants;
- efforts of participants to collaborate in identification and documentation of current trends, problems, etc. in science education from their perspective to be used by NSF for evaluation and program planning.
- extension of workshop benefits by a requirement that participants carry back to their colleagues materials and information to achieve a wider impact.

Workshops are expected to vary in length depending on the proposed nature of activity and participants. Careful attention will be paid to procedures for assuring the effectiveness of training, such as evaluations at the end of programs and the awarding of regular college credit or suitable alternatives recognition of concrete achievement. The amount requested for 1983 would allow the participation of approximately 700 science and mathematics teachers.

1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 1, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to recess, at 2:46 p.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Durbin, Gregg, McGrath, Skeen, Boehlert, Bateman, and Valentine.

Mr. Walgren. The subcommittee will be in order.

Let me call us together and we will begin today's hearing.

This is the second day of authorization hearings for the National Science Foundation, and we will look at some of the research programs of the Directorate of Astronomical, Atmospheric, Earth, and Oceanographic Sciences.

It is safe to say that the research sponsored by this Directorate has, more than any other single program, really revolutionized our view of both our planet and the universe in which we live.

If we now accept the fact that we live on continents which ride on giant plates drifting over the surface of our planet, it is due to two decades of National Science Foundation-funded research in crustal processes, both on land and at sea. Quasars, pulsars, red dwarfs, and black holes are now familiar words to a public who have watched the Cosmos and NOVA television shows with fascination and who have made three new science magazines a success in the last 3 years. Again, NSF-sponsored research is most responsible for these discoveries.

Just as an aside, one time I asked myself what I felt was the most important photograph that had been taken during my lifetime, and I kept coming back to that picture of the Earth taken from the Moon all by itself, as having really the greatest impact on our view of ourselves, our view of our lives, what we mean to each other, and what we should do with our lives for the future of mankind.

And so it is in these areas that great, great changes in Perception of each other and what is meaningful have occurred.

The accomplishments of the program supported by this directorate also point out the interdependence of science and technology. Research submersibles explored and sampled hot springs more than 1 mile below the sea surface and found unique forms of life there.

Drilling techniques developed for use in deep water enabled the ocean drilling ship *Challenger* not only to drill holes in thousands of feet of water but to find and reenter a drill hole months later for additional sampling.

In astronomy, satellites and silicon chips have both contributed to a great increase in observing sensitivity and capacity at all wavelengths with the resulting discovery of new and wondrous objects in the universe.

Clearly, for the United States to maintain a position on the forefront of scientific exploration requires not only strong support for scientists but for the engineers and technicians that design, build, and operate these expensive and sophisticated research tools.

Today we will hear about oceanography, ocean drilling, and astronomy. We will learn something about the research opportunities and the needs in these fields. I regret that time does not allow us to explore all the programs of the Directorate. I realize that the continental earth sciences and the atmospheric sciences have their own stories to tell, and I hope we will be able to hear them in the future. But I certainly want to assure those interested in those aspects of the National Science Foundation that they are not neglected by this committee in our budget reviews.

At this point I would like to, before introducing Captain Cousteau, turn to the minority for any statement they would like to make.

Mr. McGrath.

Mr. **McGrath**. Thank you, Mr. Chairman.

I would just like to welcome Captain Cousteau and Dr. Knapp and our other distinguished panelists.

Mr. **Walgren**. It now gives me great pleasure to welcome as our first witness a person who has expanded the horizons of millions of Americans who have enjoyed and been educated about the oceans by the pioneering work that he has done.

Captain Cousteau needs no introduction to the science community in the United States. We are very pleased you are here. We feel it particularly important that someone of your stature would invest the time to come and talk to us about your view of what science holds in this area. It is not lost on the other Members and on the executive branch of this Government that you are here.

So, welcome to the committee, Captain Cousteau.

Any written remarks you would like to make will be made a part of the record, and you can proceed to present your views, however you feel most comfortable and effective. It is nice that you are here.

[The biographical sketch of Captain Cousteau follows:]

Captain Jacques-Yves Cousteau

Education: Navy Academy, Crest, France

War Experience: With French underground, helped clear of Mediterranean coast of mines

Decorations: Legion of Honor, Croix de Guerre

Positions: Founder and President, Campagnies Oceanographique Francaises
Captain, RV CALYPSO
Director: Musee Oceanographique de Monaco

Accomplishments: Coinventor of the aqualung which has made possible the modern sport of scuba diving

First person to take color pictures under water

Avid diver, helped design several diving vessels

Inventor of process to use TV underwater

Has produced books, films, and TV shows on the sea over the last twenty years. These have won awards at many film festivals, including an Oscar.

Foreign member of the U.S. National Academy of Sciences (among a large number of honors and awards)

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STATEMENT OF CAPT. JACQUES-YVES COUSTEAU, PRESIDENT, COUSTEAU SOCIETY

Captain COUSTEAU. Thank you, Mr. Chairman.

If you allow me, Mr. Chairman, before I make my statement, my official statement, I would like to confess something. I am not an American citizen. But I have been raised as a boy in New York City. I played baseball on 95th Street, and I broke a number of windows at that time, with the usual consequences for kids. [Laughter.]

I came regularly back to the States when I was 16, when I was 25, and from 1951 on, every year, and since 1974 I have been spending almost half of my time here.

I have been a witness from the outside of what was going on in the United States. I feel almost like an American citizen because I pay my taxes here. I must say that I was proud of the advances, technical and scientific advances, of the United States after the war.

I was fascinated by all the progress made in oceanography, mainly, thanks to such agencies as the Office of Naval Research, which was at that time lavishly supporting basic research.

I must say that I have also witnessed, since 1968, a certain decline in the leadership in science and technology of the United States. At the same time, before 1968, the European best brains used to come here to work. Now, there is the beginning of the reverse trend, American brains going abroad.

I think it is a very serious situation. Since 1968, one after the other, the various budgets were reduced slowly, and slowly but surely for fundamental research. Only recently, since the President spoke a few encouraging words in his state of the Union address, can we hope that the trend will be reversed in the future.

I think this subcommittee has a lot to do to encourage a reversal of the trend, because the future of America is in its leadership in science and technology.

I have been asked, Mr. Chairman and members of the subcommittee, to express my views on what the goals of basic oceanographic research should be in the eighties. It is a great honor. It can only be done today, keeping in perspective the close relationship between the ocean as a whole, and the very existence of human beings.

Because we breathe air and integrate water in our bodies, it is natural that we study the atmosphere and the ocean. We have developed the study of the atmosphere and created real-time meteorology. We know at every moment what is happening in the atmosphere, using the latest devices.

It seems to me that it is high time to develop real-time oceanology. Spot measurements of temperature and salinity with conventional methods, even if these methods have been perfected, thanks to highly sophisticated instruments, such spot measurements are very difficult to coordinate precisely because the ocean is a constantly changing environment.

In order to be able to grasp the complexity of these changes, real-time data must be collected in key areas. Remote sensing must, of course, be perfected, but also thousands of inexpensive, lightweight, drifting buoys should be constantly spread over the oceans, dropped by airplanes, interrogated by satellites.

The pulse of the world oceans must be followed daily as we daily take the pulse of the world atmosphere. This is, of course, a big enterprise. It should be a cooperative international enterprise, but we do not trust the intergovernmental organizations. They have been discussing these matters for decades with no results whatsoever.

So, in order to break this inertia, I recommend to start a two-, three-, or four-nation venture. For such a fundamental and permanent study, very few ships are needed, but apart from satellites, there is a need to develop a reliable slow takeoff and landing seaplane, especially designed for oceanography.

As you know, seaplanes have been abandoned for transportation, and rightly so. But for oceanology, slow takeoff and landing seaplanes, with even a small wind, can almost takeoff and land vertically. There is such a plane made in Japan, but it is a little too small and it has not been designed specifically for the kind of operation that we would like to conduct. I very strongly recommend that such a seaplane be studied because we will need it badly in the future, and it would save millions of dollars once it is developed.

Then we have another set of problems to study: The four interfaces of the ocean. The air/ocean interface is already the object of very substantial studies the world over. That is where the climates are conceived, and it is because of the interest of meteorology specialists that this interface has been so lavishly funded.

The ocean bottom interface is where continents and ocean basins are forged, where minerals are generated and nutrients regenerated.

Well, as you know, big programs have been developed in the United States by NSF to drill into the bottom and understand better the geophysics of the Earth, but it is only one facet of this bottom study.

The coastline provinces are the third frontier of the ocean. That is where the human pressure is the highest. There is one thing that few people take into consideration. In that place along the coastline, waves breaking generate marine aerosols which spread, pushed by the wind, oligo-elements that fertilize agriculture way inland, to such an extent that some people have begun to establish a close mathematical relationship between average wind speed, size of the waves, and the fertilization of the land.

Finally, the fresh water/salt water interface is extremely important at the deltas and mouths of large and small rivers and of various runoffs.

The study of these four frontiers of the ocean calls for highly specialized equipment, very special ships, and helicopters.

Studying the ocean as a vast, living, and ever-changing environment, focusing on its main interfaces to better understand the interaction between natural forces and human increasing interference, must lead us to broader concepts.

As I understand the general direction of research presently being funded and then balance this against the problems this country and our entire global society face, I worry that some very important questions are not being addressed.

I would like today to share some thoughts on what I call ecotech. By this term, I mean the integration of such human-oriented disciplines as economics, sociology, and landscape architecture with natural system subjects such as ecology and geology, hydrology, and energy analysis.

Ecotech encompasses these academic disciplines and adds the use of appropriate technology to address the most important problem humanity faces today: The sound management and integration of human and natural processes.

We need to understand both of these domains, each in the context of the other, and we need to develop management strategies which acknowledge and promote the vital interconnections between each. We must embrace ecology, economics, and with appropriate technology, develop alternate futures to insure a healthy and productive biosphere.

As you know, my primary concern has been the ocean, first as a frontier to explore, then as a resource which should be managed wisely for continued productivity. I have consistently expressed fears that renewable ocean resources are being either overexploited or mismanaged, and that using the sea as a universal sewer will reduce its vitality and thus diminish our benefit from its resources.

But such mechanical destruction and pollution are most often considered as isolated issues separate from an integrated concept of the whole; that is, without an appreciation for how the human and natural resources interact in the entire system.

At National Science Foundation, relatively large amounts of dollars and energy have been invested in studying molecular biology and biochemistry, and the work, thanks to the NSF peer review process and other factors, has been impeccable science.

A smaller investment has been made, though, at higher levels of organization such as population ecology and ecosystem function, and, possibly due to limited information and methodologies, some have considered this soft science.

Finally, almost no support has been given to study at the level of interactions between ecosystems and human systems. I view this as a tragic mistake, since it is at this level that humans are presently exerting a major influence on the biosphere.

Of course, human influences affect lower levels as well, but processes occurring at a high level cannot be studied from a level of organization below it. This reminds me of a statement by Einstein which could be easily equated to this one.

It is at this broad or high system level where we have the most to gain, by designing systems which maximize the benefits from our environment. And it is at this level where we have the most to lose, as we can potentially destroy entire ecosystems on which we depend.

Addressing the problem at any level of organization below this will leave important questions unanswered. The limitation of the reductionist paradigm is that each discipline is unable to look beyond its own domain or above its level of organization, and, consequently, each is inadequate to address some of our most important problems and thus to develop solutions.

I feel the National Science Foundation should support holistic science as seriously as it has promoted reductionist science.

Recently I turned my attention from the sea, exclusively, to an exploration of rivers, because it was obvious that rivers have an impact on the sea as carriers of nutrients, organic matter, sediments, and pollutants. Upon exploring the Nile, the St. Lawrence, which drains the Great Lakes, and now the Amazon, it has been forcefully impressed upon me that the rivers are merely a reflection of the land area which they drain, and that in many cases this is dominated by the actions and effects of human activity.

As I travel, I am constantly reminded that natural systems and human systems are becoming more closely bound and that to understand one without considering the other is impossible. My point here is that I believe the National Science Foundation should support and develop a new, integrated science of humanity and nature which will study and direct the relationship between the two.

As I mentioned, we need a conceptual framework in which to integrate natural systems, human systems, and appropriate technology. We need to understand the patterns of the landscape including coastal regions, the human and natural systems which survive in these regions, the distribution and exchanges of energy and matter, the controlling role of water, feedback loops within these systems, and we need to be able to evaluate alternate futures in light of such models. Ultimately, this must become part of the process of policy development.

Water is a particularly appropriate example of such studies, since it is not limited by any of our artificial disciplinary boundaries. It is simultaneously a controlling force in many physical, biological, and human processes and, at the same time, is affected by each and in turn influences the remaining two.

As water brings life to ecosystems in precipitation, it also may bring death from remote sources of pollution. Water symbolizes the absolute interconnectedness of all segments of the biosphere, and attempts to answer questions about its allocation and most appropriate use interface with almost every academic discipline.

Now, when I speak of water instead of the ocean, it is because all waters originate from the ocean and we cannot disassociate freshwater systems from the salt-water system.

I urge you to assemble the most open-minded and creative people who represent such fields as geology, economics, environmental engineering, planning, ecology, sociology, oceanography, landscape architecture, energy analysis, politics and anthropology, and to encourage them to develop a new science which encompasses all segments and processes of our biosphere. Merely getting such diverse interests to communicate and to reach consensus about the domain and objectives of this subject will be a monumental task, I know.

I hope that from this will come a definition of specific projects such as the development of quantitative natural and human resource inventories, theoretical principles applicable to the entire system, integrated system models, and optimization and value-assessment techniques such as those being used by Ian McHarg and Howard T. Odum.

The techniques employed by both of these pioneers and their teams have been very helpful in guiding environmentally sound development which maximizes human benefit from nature's free services.

I am convinced that the National Science Foundation is the best organization to do this, primarily because of its success in promoting good research in other fields.

The ocean is very definitely part of this proposal, but even the ocean is only part of this system and cannot be considered as an entity isolated from all other parts. I urge you to make a commitment to support the study of humanity and nature.

Thank you.

[The prepared statement of Captain Cousteau follows:]

STATEMENT

by

CAPTAIN JACQUES-YVES COUSTEAU

Mr. Chairman, Members of the Subcommittee, distinguished colleagues,

I have been asked to express my views on what the goals of basic oceanographic research should be inthe eighties. This can only be done today - keeping in perspective the close relationship between the ocean as a whole and the very existence of human beings. Because we breathe air and integrate water in our bodies, it is natural to study the atmosphere and the ocean. We have developed the study of the atmosphere and created real-time meteorology. It seems to me that it is high time to develop real-time oceanology. Spot measurements of temperature and salinity with conventional methods, even if these methods are highly sophisticated, are difficult to coordinate precisely because the ocean is a constantly changing environment.

In order to be able to grasp the complexity of these changes, real-time data must be collected in key areas. Remote sensing must be perfected, but also thousands of inexpensive, lightweight, drifting buoys should be spread over the oceans, dropped by airplanes, interrogated by satellites. The pulse of the world oceans must be followed daily, as we daily take the pulse of the world atmosphere. This is a cooperative international enterprise, but one way to break the inertia of intergovernmental organizations is to start a two, three or four nation venture. For such a fundamental and permanent study, very few ships are needed, but apart from satellites, there is a need to develop a reliable slow take off and landing seaplane, specially designed for oceanography.

Then we have another set of problems to study - the four interfaces of the ocean: the air/ocean interface where climates are conceived. The ocean bottom interface, where continents and ocean basins are forged, where minerals are generated and nutrients regenerated. The coastline provinces where the human pressure is highest, where marine aerosols spread oligo-elements that fertilize agriculture way inland. And finally, the fresh water/salt water interface, at deltas and mouths of large and small rivers, and of various run-offs. The study of these four frontiers of the ocean calls for highly specialized equipment, very special ships and helicopters.

Studying the ocean as a vast, living and ever changing environment, focusing on its main interfaces to better understand the interaction between natural forces and human increasing interference, must lead us to broader concepts.

As i understand the general direction of research presently being funded and then balance this against the problems this country and our entire global society face, I worry that some very important questions are not being addressed. I would like today to share some thoughts on what I call Ecotech. By this term, I mean the integration of such human oriented disciplines as economics, sociology, ~~policy~~, and landscape architecture with natural system subjects such as ecology and geology, hydrology, and energy analysis. Ecotech encompasses these academic disciplines and adds the use of appropriate technology to address the most important problem humanity faces today: the sound management and integration of human and natural processes. We need to understand both of these domains, each in the context of the other, and we need to develop management strategies which acknowledge and promote the vital interconnections between each. We must embrace ecology, economics, and with appropriate technology, develop alternate futures to insure a healthy and productive biosphere.

As you know, my primary concern has been the ocean, first as a frontier to explore, then as a resource which should be managed wisely for continued productivity. I have consistently expressed fears that renewable ocean resources are being overexploited and that using the seas as a universal sewer will reduce its vitality and thus diminish our benefit from its resources. But such mechanical destruction and pollution are most often considered as isolated issues separate from an integrated concept of the whole; that is, without an appreciation for how the human and natural resources interact in the entire system.

At NSF, relatively large amounts of dollars and energy have been invested in studying molecular biology and biochemistry, and the work, thanks to the NSF peer review process and other factors, has been impeccable science. A smaller investment has been made, though, at higher levels of organization such as population ecology and ecosystem function and, possibly due to limited information and methodologies, some have considered this soft science. Finally, almost no support has been given to study at the level of interactions between ecosystems and human systems. I view this as a tragic mistake since it is at this level that humans are presently exerting a major influence on the biosphere. Of course, human influences affect lower levels as well, but processes occurring at a high level cannot be studied from a level of organization below it. It is at this broad or high system level where we have the most to gain, by designing systems which maximize the benefits from our environment. And it is at this level where we have the most to lose as we can potentially destroy entire ecosystems on which we depend. Addressing the problem at any level of organization below this will leave important questions unanswered. The limitation of the reductionist paradigm is that each discipline is unable to look beyond its own domain or above its level of organization and, consequently,....

each is inadequate to address some of our most important problems and thus to develop solutions. I feel NSF should support holistic science as seriously as it has promoted reductionist science.

Recently I turned my attention from the sea, exclusively, to an exploration of rivers because it was obvious that rivers have an impact on the sea as carriers of nutrients, organic matter, sediments and pollutants. Upon exploring the Nile, the St. Lawrence which drains the Great Lakes, and now the Amazon, it has been forcefully impressed upon me that the rivers are merely a reflection of the land area which they drain, and that in many cases this is dominated by the actions and effects of human activity. As I travel, I am constantly reminded that natural systems and human systems are becoming more closely bound and that to understand one without considering the other is impossible. My point here is that I believe the NSF should support and develop a new, integrated science of humanity and nature which will study and direct the relationship between the two.

As I mentioned, we need a conceptual framework in which to integrate natural systems, human systems, and appropriate technology. We need to understand the patterns of the landscape including coastal regions, the human and natural systems which survive in these regions, the distribution and exchanges of energy and matter, the controlling role of water, feed back loops within these systems, and we need to be able to evaluate alternate futures in light of such models. Ultimately, this must become part of the process of policy development.

Water is a particularly appropriate example since it is not limited by any of our artificial disciplinary boundaries.

It is simultaneously a controlling force in many physical, biological, and human processes and at the same time is affected by each, in turn influences the remaining two. As water brings life to ecosystems in precipitation, it also may bring death from remote sources of pollution. Water symbolizes the absolute interconnectedness of all segments of the biosphere and attempts to answer questions about its allocation and most appropriate use interface with almost every academic discipline.

I urge you to assemble the most open-minded and creative people who represent such fields as geology, economics, environmental engineering, planning, ecology, ~~policy~~, sociology, oceanography, landscape architecture, energy analysis, politics and anthropology - and to encourage them to develop a new science which emcompasses all segments and processes of our biosphere. Merely getting such diverse interests to communicate and to reach consensus about the domain and objectives of this subject will be a monumental task. I hope that from this will come a definition of specific projects such as the development of quantitative natural and human resource inventories, theoretical principles applicable to the entire system, integrated system models, and optimization and value-assessment techniques such as those being used by Ian McHarg and Howard T. Odum. The techniques employed by both of these pioneers and their teams have been very helpful in guiding environmentally sound development which maximizes human benefit from nature's free services. I am convinced that NSF is the best organization to do this, primarily because of its success in promoting good research in other fields.

The ocean is very definitely part of this proposal, but even the ocean is only part of this system and cannot be considered as an entity isolated from all other parts. I urge you to make a commitment to support the study of humanity and nature.

Mr. **Walgren**. Thank you very much, Captain Cousteau.

That is a powerful and large statement.

I cannot help but bring to mind that the United States seems to have been pulling back from exactly some of the directions that you indicate it makes sense to go in. I think of our at least governmental withdrawal from some international scientific agencies that were trying to, as I understand it, look at global resources—the IASA group in Austria, in particular.

Has that become evident in your view of the U.S. scientific community from an international perspective? How are events like that perceived in the international scientific community?

Captain **Cousteau**. As you know, Mr. Chairman, the trends in science have been traditionally set by this country. After the war and until that fatal date of 1968, a large share of the funds was allotted to fundamental research, basic research. Since 1968, the fashion, the trend, is to encourage applied science.

Applied science generates improvements, never any breakthroughs. It is only basic science that brings about the breakthroughs. So there has to be a balance between the two. I do not think that at this stage it is the case.

I must say that all the other countries have followed the example of the United States, exactly like the women of the world follow the trend of French fashion.

Mr. **Walgren**. Is there a reason why 1968 was a watershed, emphasizing applied science thereafter?

Captain **Cousteau**. I think that is the time when, by a series of bills—in Europe, we call it the Johnson Act, but in fact it is a series of bills which have forbidden or made it difficult for the military to fund research that is not directly aimed at military goals.

When you know the amount of breakthroughs that have been made in oceanography, thanks to the funding of the Office of Naval Research, you understand that from then on that was finished. I think it was a fatal blow.

Mr. **Walgren**. That was the Johnson Act?

Captain **Cousteau**. It was during Johnson's Presidency. We simplify abroad the intricate American bills by calling it the Johnson Act when we want to criticize this attitude.

Mr. **Walgren**. And it directed things away from——

Captain **Cousteau**. Yes, from fundamental research.

Mr. **Walgren**. From fundamental research in the military in particular?

Captain **Cousteau**. No, no, not only. From then on, the scientists had to justify that their research would bring about material advantages.

Mr. **Walgren**. I see.

Captain **Cousteau**. They couldn't care less, but they have to season their application.

Mr. **Walgren**. I see.

Let me ask what the barriers are to greater international cooperation and how we can encourage more cooperation. I know it is a broad subject, but I do sense in certain areas our Government is pulling back into a kind of nationalism, even to the point of concern about spread of information, literally, abroad, in apprehension that it has some security connotations. Yet it is clear that the scientific community certainly has to be a worldwide community.

What are some of the real barriers to international cooperation that you have experienced, and do you have any advice for us in that area?

Captain COUSTEAU. Well, as you know, I have not experienced, myself, anything directly because we are completely self-supported, and we do not receive any government funds from any country, whether it is the Oceanographic Institute of Monaco or the Cousteau Foundation. We don't want any government funds, in order to be completely free. But that is exceptional, so let's forget about my own direct experience.

I was very struck when I went to the Jet Propulsion Laboratory several times at the time when they were preparing Sea-Sat. It was a long time that we were waiting for a satellite specifically aimed at oceanic exploration. The earth satellites have given some information, but they were not prepared for that kind of job.

I was disappointed to see the program of Sea-Sat, in spite of the fact that it had some very interesting instruments. I asked why the program of Sea-Sat had not been more broadly aimed at the open ocean. Sea-Sat was aimed at the coastal ocean, and I asked why. It was for political reasons, because public funds of that magnitude would be easier to get if it was for domestic waters. It doesn't make any sense to me, because that very same satellite was spinning around the world, going over the coastal areas of all nations, and could have been aimed at bringing about a fantastic amount of information on the open ocean. Unfortunately, Sea-Sat had a very short life.

But this is the example that I can give of this kind of nationalistic myopy.

Another barrier is, as I said in my statement, the inefficiency of intergovernmental organizations, the inertia, the time lost in congresses and meetings and talks, and nothing is done, and money is spent just in travel expenses and meetings.

A very good example of what could be done was the collaboration between the United States and France for the study of the mid-Atlantic ridge. When I was suggesting that the cost of spreading inexpensive buoys over the ocean being high, it could be shared between a few nations without passing through the international organizations. I think that several countries would be ready to go, with the United States. This is the type of thing, in answer to your question.

Mr. WALGREN. Thinking again about the trends in nationalism, it is my understanding that there now is more and more effort to extend the coastal reach of nations now out to 200 miles in their control and jurisdiction completely. Is that going to have an impact on international science? Will oceanographers find that direction limiting?

Captain COUSTEAU. It has to be seen, and we will know that very soon.

Now, it is impossible for me, Mr. Chairman, to answer objectively that question. I am obliged to answer subjectively because I am a violent opponent of the Law of the Sea. I think the butchering of the oceans, the dividing of it into 200-mile limits, of sovereignty, national sovereignty, instead of dividing it into zones of responsibility, was a tremendous mistake.

I am not an opponent of the Law of the Sea for the same reasons that the Government of the United States is; it is for entirely different reasons.

As a consequence, also, I am sure that scientific ships will have greater problems working in some of those national sovereignty zones. This is sure.

Mr. **Walgren**. Yes.

Captain **Cousteau**. Now, for your information, there is a meeting in Nice this year in October, I think, to establish, using legal advice as well as scientific advice, a file defending free access for scientists into these zones. This is going to be a very interesting meeting, and I am going to attend.

Mr. **Walgren**. You know, in our National Science Foundation, in particular, we have, over the last short period of time, had difficulty keeping funding for social sciences, and it comes through loud and clear in your statement that somehow you feel we have to include man in this whole process and somehow approach it from a perspective that starts on the higher level, I gather, and you mentioned this principle of the science of reduction versus whatever the alternative is.

Captain **Cousteau**. May I, Mr. Chairman, quote Einstein?

Mr. **Walgren**. Please.

Captain **Cousteau**. I always carry it with me because I should not forget it.

> The world that we have made as a result of the level of thinking we have done thus far creates problems that we cannot solve at the same level as the level we created them at.

Mr. **Walgren**. We cannot solve at the same level as——

Captain **Cousteau**. As the level we created them at. That clearly says, if we carry on with studying little facts, we are going nowhere. We have to go to the high level to understand the problems that we have created at the lower level. So it is a must for us now that we have already a big area of understanding about this world, thanks to scientific research in the past; it is high time to get to the higher level.

Mr. **Walgren**. That higher level would certainly emphasize starting with man and his interaction.

Captain **Cousteau**. Yes, exactly.

Mr. **Walgren**. Have you been down to the Vietnam war memorial in our country here yet?

Captain **Cousteau**. No, sir.

Mr. **Walgren**. I know you will get there sometime soon. One of the strangest juxtapositions is the fact that it is less than 25 yards from the Einstein memorial, and going between the two is something that perhaps will bring some very real realizations on the part of many people about these different levels and how we have failed so completely on some levels.

Well, I am sorry to have gone on, and we have other members, in order of their appearance. Mr. Skeen.

Mr. **Skeen**. I have no questions, Mr. Chairman.

I just want to say to Captain Cousteau that, as a long-time admirer of yours, it is a pleasure to sit here and listen to you today. It is a time for us to learn something, and I for one have learned a great deal.

I particularly appreciate the straightforward method in which you answered the questions and the candor. It is a very rare thing—and also how well you are able to separate reality from politics.

Thank you, Captain. I enjoyed it.

Captain COUSTEAU. Thank you, sir.

Mr. WALGREN. Thank you, Mr. Skeen.

Mr. Durbin.

Mr. DURBIN. Thank you.

I want to repeat what Congressman Skeen has said. I consider it an honor to be here with you today.

I have several small children at home, and when I come home every week, as I do, in Springfield, Ill., too far away from the ocean, they ask me what happened this week, and I am sure everything that has happened to me will be dwarfed by the fact that I sat in a committee with Captain Cousteau.

I would like to ask you a simple question, perhaps reflecting my own naivete or apprenticeship when it comes to this area. If you were to sit with a group of young people today who live, as I do, in the hinterlands, in the mainland of the United States, and wanted to know why it was important for us to keep plumbing the depths of the ocean and looking in the oceans and rivers for our future, what would you tell them? What exciting horizons do you see there that we all should appreciate, many of us who are 1,000 miles away from the ocean?

Captain COUSTEAU. I would try to explain to them that the ocean is the fuel for the big thermodynamic machine that we are living in, and that without a well functioning ocean, the potatoes would not grow in Idaho.

It is fairly easy to demonstrate, but we depend on little factors, like for example, the evaporation factor of the surface of the ocean to build up vapor and rain. The extensive pollution of that surface may bring about a reduction of the evaporation; on the contrary, may heat the molecular surface of the ocean to such an extent that it would increase the evaporation. In the first case, it would bring about drought and famine. In the second case, it would bring about floods and a rise in the level of the ocean, with the flooding of most of the coastal cities.

So we have to understand that this thermodynamic machine is extremely fragile and sharp. It works on a needle, and any kind of interference can bring about such things as glaciation or other consequences.

Mr. DURBIN. What do you see as the next horizon in oceanographic research? Where are we looking when we think in terms of research rather than application that you have seen from your own experiences?

Captain COUSTEAU. It is obvious, to start with, that there can be a lot of resources taken from the ocean, not necessarily those that are emphasized in the newspaper, but from the research standpoint. We have to better understand how the ocean works for our own survival, not speaking about material benefits, because we are just depending upon that well functioning, clockwork machinery.

Any disturbance could bring about disastrous consequences. So we have to understand. That is why I was referring to organized real-time oceanology. We should know what is happening in the ocean as fast and as completely as we know what is happening in the air, in the atmosphere and we do not. We are far from that, and we should, because otherwise we will not be in a position to avoid disasters.

Mr. **DURBIN**. Thank you very much, Captain.

Mr. **WALGREN**. Thank you, Mr. Durbin.

Mr. Bateman.

Mr. **BATEMAN**. Mr. Chairman, I will not offer any questions. I would like to comment that I was first privileged to hear Captain Cousteau as a witness before a legislative body in the General Assembly of Virginia.

Captain, it is good to hear from you again. Had I known you were going to be a witness this afternoon, I would have been absent somewhere else instead of absent from here, but I am glad I got here for a part of your presentation.

Mr. **WALGREN**. Thank you very much, Mr. Bateman.

Well, let me, on behalf of the committee, express our appreciation for your presence and the investment you have made in trying to give us your perspective. We appreciate it very much.

Captain **COUSTEAU**. Thank you, Mr. Chairman.

Mr. **WALGREN**. Thank you very much.

The next witness is Dr. Edward Knapp, again the Director of the National Science Foundation.

One of the benefits of these hearings is we bring together in the same room people who are in a position to learn a great deal from each other and, in this instance, act on it. I am sure that there will be that kind of synergistic effect.

Dr. Knapp is accompanied by Dr. Edwin Salpeter, who is a member of the National Science Board, and we are pleased to have you gentlemen.

Your written statements will be made part of the record without more, and please feel free to summarize your views and presentations as you feel effective.

Dr. Knapp.

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. EDWIN A. SALPETER, MEMBER, NATIONAL SCIENCE BOARD

Dr. **KNAPP**. Thank you, Mr. Chairman.

I will summarize my written statement and submit it for the record.

It is a pleasure to testify again today and to be accompanied by Dr. Edwin Salpeter, a member of the National Science Board, and J. G. White, Professor of Physical Sciences at Cornell University.

Today we have an opportunity to discuss some areas of science that are among the most exciting supported by the Foundation. Plate tectonics, for example, has been heralded by many as a scientific revolution comparable in significance to the Newtonian synthesis or the Darwinian theory of evolution.

Astronomers have observed unexplained phenomena occurring in the galaxy's core which involve prodigious amounts of energy. In the Earth's crust, hot springs have been discovered in which unexpected biological and mineral processes are occurring.

The violence and frequency of wind downbursts associated with thunderstorms have been found to be important as a probable cause of airplane crashes on takeoff and landing.

These and many other significant discoveries and developments have occurred in the last decade or so in the astronomical, atmospheric, Earth and ocean sciences which are the focus of today's hearing.

It is important to understand something about the general character of these disciplines—their sociology, if you like. Their character shapes their structure, the way in which scientists themselves conduct research, their resource requirements, and the way in which the Foundation budgets for them and manages the research programs supporting them.

The primary characteristics of these sciences are that they are observational sciences; they are multidisciplinary; and they are defined in terms of particular environmental domain or location.

In general, researchers in these fields study the phenomena of interest without being able directly to control and manipulate them as in the laboratory sciences. They seek and observe particular natural phenomena of the Earth and the universe.

The observational character of these sciences means that they are highly dependent upon instrumentation, in the broadest sense of the word—drilling platforms, astronomical observatories, aircraft, ships, submersibles, seismic detectors, earth corers, and computational equipment for handling data, facilitating its interpretation, and modeling natural phenomena.

The equipment is costly to purchase or construct and to operate. It requires a sizable support and technical staff plus a sophisticated division of labor to use, maintain, and further develop it.

These sciences lend themselves to coordinated group undertakings by investigators in different disciplines, different institutions, and different countries. This condition exists because coordinated measurements of various phenomena within a known time period in the same location can improve overall scientific understanding.

In astronomy, for example, simultaneous observations from several radio telescopes located at a distance from each other have made possible significantly improved resolution of distant stellar systems.

The Foundation is a major supporter of academic research in all the AAEO sciences, although the magnitude of its role varies, depending on the level of funding for more mission-oriented research provided by other Federal agencies.

The NSF is the lead agency for Federal support of ground-based astronomy and, since 1976, has maintained a relatively constant funding role, providing about two-thirds of the Federal total for such research.

In atmospheric sciences research, the National Oceanic and Atmospheric Administration, the Department of Defense, and the National Aeronautics and Space Administration are major sources of support. NSF funding accounts for only about half of the atmospheric research conducted by university investigators.

The U.S. Geological Survey, NASA, and the Department of Energy are important funders of applied, mission-oriented work in the Earth sciences. But the Foundation accounts for about 75 percent of the Federal funds going to universities for support of basic research in these disciplines.

Similarly, the NSF provides nearly three-fourths of the Federal support of basic ocean research at academic institutions.

The Foundation support for research in the astronomical, atmospheric, Earth, and ocean sciences is provided in four dominant modes: direct support of individual investigators to cover such costs as developing instruments required for their experiments, data analysis, and post-doctoral and graduate research assistants; support of national centers and other major research facilities; support for large coordinated projects; and indirect support of many investigators who are given access to facilities, data, or samples on a competitive basis.

The major facilities which the Foundation supports in these disciplines include: five user-oriented national astronomical observatories, and partial support of a half dozen university observatories that operate a range of radio telescopes; the National Center for Atmospheric Research, which conducts staff research itself and provides major computational and modeling facilities, aircraft, and radars to university researchers; seismic reflection profiling by the Consortium for Continental Reflection Profiling [COCORP], to map the structure of the continental crust to a depth of 70 kilometers; and the ocean drilling ship *Challenger* and associated core repositories and geophysical data banks.

Individual project support is also provided in all of these scientific disciplines, although the proportions vary from field to field. In the Earth sciences, for example, the bulk of the funding is for small awards to individuals. In contrast, more than two-thirds of the budget for research in astronomy goes to the national and university observatories.

The balance between facilities development, operation and maintenance, and project grants is carefully examined each year by the NSF staff with advice from their scientific advisory committees. The National Science Board also reviews each of these programs from time to time and examines the balance among their various activities and modes of support.

Access to facilities and coordination of their scientific use is accomplished in different ways in each discipline. But in all cases, decisions are based on competitive peer review.

These facilities make possible a large number of individual projects. For example, well over 1,000 astronomers use the national observatories each year for their projects. Similarly, deep sea cores from the *Challenger* program are requested and used by large numbers of marine geologists and geophysicists.

Over the years, the House Science and Technology Committee has taken the leadership in recognizing some of the questions to be addressed in budgeting for and managing complex activities such as these.

Within the framework of a policy statement adopted by the National Science Board in 1979, in response to a recommendation from your committee, these questions are addressed at several different levels within the Foundation as a part of its planning and budgeting processes. They are addressed by the NSF staff and its scientific advisory panels. They are also reviewed by the National Science Board and by myself.

In addition, when we anticipate the initiation of major new facilities or the phasing out of major existing facilities, they are closely reviewed by the Office of Management and Budget and the Office of Science and Technology Policy before being submitted to Congress.

I am pleased that NSF is proposing an increase of 21.3 percent in the level of support for astronomical, atmospheric, earth and ocean sciences for fiscal year 1984. The Foundation is planning a major emphasis on the astronomical sciences with a 25.9-percent increase in this rapidly advancing and scientifically exciting area. The increase will allow NSF to upgrade instrumentation at university and national observatories and to support preliminary design studies for the very long baseline array.

The emphasis on earth sciences in the past few Foundation budgets is continued into fiscal year 1984. The increase will allow year-round, continental reflection profiling operations and general upgrading of much of the research instrumentation that has become obsolete since the major Federal equipment investments of the 1960s.

In fiscal year 1984, the Foundation expects to invest about $68 million to support crustal research. Included in this funding is $26.3 million for the ocean drilling program, which is now in the AAEO activity and which provides funds adequate to continue the deep sea drilling program.

A distinguished committee of earth and ocean scientists has reviewed priorities and directions for crustal research; its chairman is with us this afternoon. Their recommendation, not yet published, is to continue ocean drilling, preferably with a large, modern, leased commercial drill ship. This preliminary recommendation is under review by the Foundation. If the Foundation and the administration concur with it, we will expect to present appropriate program recommendations to the Congress.

Mr. Chairman, I am extremely pleased that the President's budget request for the Foundation proposes an 18.3 percent increase over fiscal year 1983 for the support of basic research. In the sciences we have been discussing today, this increase will allow us to upgrade instrumentation for astronomical and geological research, expand support of graduate student research assistants and research post-doctorates, expand activities in the exciting area of crustal research, initiate design studies of a major new astronomical facility, and maintain the level of NSF core programs and activities. These are investments in the Nation's scientific and technical future. I hope this committee will strongly endorse them.

Dr. Salpeter and I will be pleased to answer any questions you may have.

[The prepared statement of Dr. Knapp follows:]

STATEMENT OF
DR. EDWARD A. KNAPP
DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
MARCH 1, 1983

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

IT IS A PLEASURE TO BE BACK BEFORE YOU TODAY AND TO BE ACCOMPANIED BY DR. EDWIN E. SALPETER, A MEMBER OF THE NATIONAL SCIENCE BOARD AND J.G. WHITE PROFESSOR OF PHYSICAL SCIENCES AT CORNELL UNIVERSITY.

TODAY, WE HAVE AN OPPORTUNITY TO DISCUSS SOME AREAS OF SCIENCE THAT ARE AMONG THE MOST EXCITING WHICH THE FOUNDATION SUPPORTS. PLATE TECTONICS HAS BEEN HERALDED BY MANY AS A SCIENTIFIC REVOLUTION COMPARABLE IN ITS SIGNIFICANCE TO THE NEWTONIAN SYNTHESIS OR THE DARWINIAN THEORY OF EVOLUTION. ASTRONOMERS HAVE OBSERVED UNEXPLAINED PHENOMENA OCCURRING IN THE CORE OF OUR GALAXY WHICH INVOLVE PRODIGIOUS AMOUNTS OF ENERGY. IN THE EARTH'S CRUST, HOT SPRINGS HAVE BEEN DISCOVERED IN WHICH UNEXPECTED BIOLOGICAL AND MINERAL PROCESSES ARE OCCURRING. THE VIOLENCE AND FREQUENCY OF WIND DOWNBURSTS ASSOCIATED WITH THUNDERSTORMS HAVE BEEN FOUND TO BE IMPORTANT AS A PROBABLE CAUSE OF AIRPLANE CRASHES ON LANDING AND TAKEOFF.

THESE AND MANY OTHER SIGNIFICANT DISCOVERIES AND DEVELOPMENTS HAVE OCCURRED IN THE LAST DECADE OR SO IN THE ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES WHICH ARE THE FOCUS OF TODAY'S HEARINGS. I WOULD LIKE TO TOUCH UPON FOUR THINGS IN MY REMARKS THIS AFTERNOON AND, WHEN I HAVE FINISHED, DR. SALPETER AND I WILL BE PLEASED TO ANSWER ANY QUESTIONS YOU MAY HAVE.

FIRST, IT IS IMPORTANT TO UNDERSTAND SOMETHING ABOUT THE GENERAL CHARACTER OF THESE DISCIPLINES -- THEIR SOCIOLOGY, IF YOU LIKE. THEIR CHARACTER SHAPES THEIR STRUCTURE, THE WAY IN WHICH SCIENTISTS IN THEM CONDUCT RESEARCH, THEIR RESOURCE REQUIREMENTS, AND THE WAY IN WHICH THE FOUNDATION BUDGETS FOR THEM AND MANAGES THE RESEARCH PROGRAMS WHICH SUPPORT THEM. SECOND, AS A SCIENTIST MYSELF, I WOULD LIKE TO SHARE WITH YOU SOME OF THE EXCITEMENT OF RECENT DISCOVERIES AND DEVELOPMENTS IN THE EARTH AND OCEAN SCIENCES. THIRD, I WILL BRIEFLY DESCRIBE THE MODES OF SUPPORT CHARACTERIZING THE FOUNDATION'S PROGRAMS IN THESE SCIENTIFIC DISCIPLINES AND HOW WE PLAN AND BUDGET FOR THEM. FINALLY, I WILL DIRECT YOUR ATTENTION TOWARDS SOME OF THE HIGHLIGHTS OF OUR FY 1984 PROGRAM IN THESE SCIENCES.

CHARACTERISTICS OF THE DISCIPLINES

THE PRIMARY CHARACTERISTICS OF THE ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES ARE THAT THEY ARE OBSERVATIONAL SCIENCES; THEY ARE MULTI-DISCIPLINARY; AND THEY ARE DEFINED IN TERMS OF A PARTICULAR ENVIRONMENTAL DOMAIN OR LOCATION. IN GENERAL, RESEARCHERS IN THESE FIELDS STUDY THE PHENOMENA OF INTEREST WITHOUT BEING ABLE, DIRECTLY, TO CONTROL AND MANIPULATE THEM AS IN THE LABORATORY SCIENCES. THEY SEEK AND OBSERVE PARTICULAR NATURAL PHENOMENA OF THE EARTH AND UNIVERSE.

THE ENVIRONMENTAL DOMAIN IS IMPORTANT. IT IS THE ORGANIZING REFERENCE POINT FOR GROUPS OF SCIENTISTS WHO OTHERWISE MAY BE QUITE DIFFERENT IN TERMS OF THE INSTRUMENTS THEY USE FOR THEIR OBSERVATIONS; THE SYSTEM LEVEL THEY OBSERVE, E.G., FROM THE DROPLETS IN A CLOUD TO MAJOR STORM SYSTEMS; THE MAJOR THEORETICAL CONSTRUCTS THEY EMPLOY FOR INTERPRETING THEIR OBSERVATIONS; AND THE SPECIFIC PHENOMENA -- BIOLOGICAL, CHEMICAL, PHYSICAL -- THEY ACTUALLY STUDY. SOME OF THESE SPECIALTIES, SUCH AS ASTRONOMY AND OCEANOGRAPHY, ARE CONCENTRATED IN A LIMITED NUMBER OF MAJOR ACADEMIC INSTITUTIONS WHILE OTHERS, SUCH AS GEOLOGY, ARE TO BE FOUND IN MOST COLLEGES AND UNIVERSITIES. BECAUSE OF THIS CONSIDERABLE DIVERSITY, IT CAN BE DIFFICULT, AT TIMES, FOR AGREEMENT TO BE ACHIEVED ON RESEARCH PRIORITIES AND RESOURCE NEEDS EVEN WITHIN INDIVIDUAL AREAS OF RESEARCH.

THE OBSERVATIONAL CHARACTER OF THESE SCIENCES MEANS THAT THEY ARE HIGHLY DEPENDENT ON INSTRUMENTATION, IN THE BROADEST SENSE OF THE WORD -- FACILITIES SUCH AS DRILLING PLATFORMS, ASTRONOMICAL OBSERVATORIES, AIRCRAFT, SHIPS AND SUBMERSIBLES FOR OBSERVATIONS FROM THE BEST LOCATIONS; SPECIFIC DATA COLLECTING DEVICES SUCH AS RADIO TELESCOPES AND RECEIVERS, CHARGE COUPLED DETECTOR ARRAYS, SEISMIC DETECTORS, EARTH CORERS, OR DOPPLER RADARS; AND STORAGE AND COMPUTATIONAL EQUIPMENT FOR HANDLING DATA, FACILITATING ITS INTERPRETATION AND MODELLING NATURAL PHENOMENA. AS INSTRUMENTS HAVE IMPROVED IN TERMS OF THEIR SENSITIVITY, RELIABILITY, OR EFFICIENCY, OR AS WHOLE NEW CLASSES OF INSTRUMENTS HAVE BECOME AVAILABLE, E.G., CHARGED COUPLED DETECTOR ARRAYS FOR COLLECTING LIGHT OR SUPERCOMPUTERS FOR INCREASINGLY SOPHISTICATED MODELLING, THEY HAVE HAD PROFOUND IMPACTS ON CONCEPTUAL UNDERSTANDINGS IN THESE SCIENCES AND HAVE REVEALED NEW, AND SOMETIMES UNEXPECTED, PHENOMENA.

Major instruments and facilities are of major importance to the conduct of research in the astronomical, atmospheric, earth and ocean sciences. The equipment is costly to purchase, or construct, and to operate; and it requires a sizable support and technical staff plus a sophisticated division of labor to use, maintain, and further develop it. As any of you who have visted the Kitt Peak National Observatory near Tucson know, the image of the lone astronomer, sitting on an isolated hill, gazing at the stars through his own telescope and recording his observations in a notebook, is at least as out of date as the 'good 5-cent cigar.' In fact, the use of sensitive photographic plates has been largely superseded by the charge-coupled detectors mentioned earlier, and data are recorded on magnetic tape and observed on TV monitors.

It is also the case that these sciences lend themselves to coordinated, group undertakings by investigators in different disciplines, different institutions and different countries. In general, this condition exists because coordinated measurements of various phenomena within a known time period in the same location can improve overall scientific understanding of the domain of interest and its parameters.

In astronomy, for example, simultaneous observations from several radio telescopes located at a distance from each other has made significantly improved resolution of distant stellar systems possible. In the last decade, a Very Long Baseline Interferometer (VLBI) network has employed various radio telescopes in the U.S. and Europe to make such detailed observations. To be successful, this work requires careful coordination of telescopes at different sites, the use of atomic clocks to indicate the precise time of recording observations, and the central collection and correlation of recorded

OBSERVATIONS IN ORDER TO PRODUCE A MAP OF THE STELLAR OBJECT OR REGION OBSERVED. THE VLBI NETWORK HAS BEEN COORDINATED BY AN INFORMAL COMMITTEE OF SCIENTISTS INVOLVED IN THE WORK, MANY OF WHOM RECEIVE SUPPORT FROM THE NATIONAL SCIENCE FOUNDATION.

THE FOUNDATION IS A MAJOR SUPPORTER OF ACADEMIC RESEARCH IN ALL THE AAEO SCIENCES THOUGH THE MAGNITUDE OF IS ROLE VARIES, DEPENDING ON THE LEVELS OF FUNDING FOR MORE MISSION-ORIENTED RESEARCH PROVIDED BY OTHER FEDERAL AGENCIES. THE NSF IS THE LEAD AGENCY FOR FEDERAL SUPPORT OF GROUND-BASED ASTRONOMY AND, SINCE 1976, HAS MAINTAINED A RELATIVELY CONSTANT FUNDING ROLE PROVIDING ABOUT TWO-THIRDS OF THE FEDERAL TOTAL. IN ATMOSPHERIC SCIENCES RESEARCH, THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA), THE DEPARTMENT OF DEFENSE (DOD), AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA) ARE MAJOR SOURCES OF SUPPORT, WITH NSF FUNDING ACCOUNTING FOR ONLY ABOUT HALF OF THE WORK CONDUCTED BY UNIVERSITY INVESTIGATORS. THE U.S. GEOLOGICAL SURVEY, NASA, AND DEPARTMENT OF ENERGY ARE IMPORTANT FUNDERS OF APPLIED, MISSION-ORIENTED WORK IN THE EARTH SCIENCES WITH THE FOUNDATION ACCOUNTING FOR ABOUT 75 PERCENT OF THE FEDERAL FUNDS GOING TO UNIVERSITIES FOR THE SUPPORT OF BASIC RESEARCH IN THESE DISCIPLINES. SIMILARLY, THE NSF PROVIDES NEARLY THREE-FOURTHS OF THE FEDERAL SUPPORT OF BASIC OCEAN RESEARCH AT ACADEMIC INSTITUTIONS. THE SIGNIFICANCE OF THE FOUNDATION'S ROLE IN THE OCEAN SCIENCES IN RECENT YEARS HAS INCREASED BECAUSE OF GENERAL DECREASES IN FUNDING LEVELS FOR BASIC AND APPLIED OCEANOGRAPHIC WORK IN OTHER FEDERAL AGENCIES.

GIVEN THESE OVERALL SUPPORT PATTERNS AS WELL AS THE GENERAL MULTI-DISCIPLINARY AND MULTI-INSTITUTIONAL CHARACTER OF THESE SCIENCES, THE FOUNDATION CLOSELY COORDINATES ITS PROGRAM PLANNING AND FUNDING ACTIVITIES WITH THOSE OF OTHER FEDERAL AGENCIES. THIS COORDINATION RANGES FROM FORMAL MECHANISMS SUCH AS THE

Committee on Atmosphere and Oceans of the Federal Coordinating Council on Science, Engineering and Technology to frequent informal contacts of NSF program managers with their counterparts elsewhere.

ADVANCES IN UNDERSTANDING: THE EARTH'S CRUST

Exceptional advances in basic understanding of geophysical and astronomical phenomena have taken place in the past two decades, in large part as a direct result of three things: significant improvements in instrumentation and facilities; expanded support for the organization and conduct of multi-disciplinary coordinated investigations in space, in the earth's atmosphere, and underneath the earth's crust and oceans; and major discoveries across the broad front of the underlying scientific disciplines and specialties.

Perhaps nowhere is this better illustrated than in research on the lithosphere, or earth's crust, and the emergence of the plate tectonics concept as a major unifying and predictive theory for this work. Even as the Newtonian synthesis provided a coherent mechanism for relating the motions of the planets to each other and to the motion of bodies on earth, so the plate tectonics concept provides a means for relating the dynamics of the ocean crust to the dynamics of the mantle, for correlating heretofore diverse ocean basin processes to one another, and for relating the evolution of the oceans and continental crusts. We estimate that in FY 1983, the Foundation will obligate $51 million to its various programs in support of such crustal research. In FY 1984, funding of this type of multi-disciplinary work will increase to an estimated $68 million.

THE ORIGINS OF OUR PRESENT CONFIDENCE IN PLATE TECTONICS THEORY GO BACK TO THE EARLY YEARS OF THIS CENTURY. BY ABOUT FIFTY YEARS AGO, MOST GEOLOGISTS HAD AGREED ON A MODEL OF THE EARTH CONSISTING OF A TWO-PART CORE -- INNER AND OUTER -- OVERLAID BY THE MANTLE, I.E., THE BULK OF THE EARTH, OVERLAID, AGAIN, BY A VERY THIN CRUST. OF THESE LAYERS, THE OUTER CORE IS LIQUID; THE REST IS SOLID. IN 1915, A GERMAN GEOLOGIST HAD PROPOSED THAT CONTINENTS WERE NOT FIXED BUT DRIFTED SLOWLY AROUND THE OCEANS. HIS THEORY WAS NOT TAKEN SERIOUSLY HOWEVER, IN PART, BECAUSE NO PLAUSIBLE MECHANISM WAS ADVANCED TO EXPLAIN THIS CONTINENTAL DRIFT.

THE PLATE TECTONICS THEORY, ESTABLISHED JUST TWO DECADES AGO ON THE BASIS OF DETAILED MAGNETIC MAPPING OF THE OCEAN FLOOR AND ANALYSIS OF OCEAN BASIN SEDIMENTS AND ROCK, PROVIDED A PLAUSIBLE MECHANISM FOR THIS HYPOTHESIS AND LINKED THAT MECHANISM TO THE THERMAL PROCESSES OCCURRING WITHIN THE EARTH'S INTERIOR. BEFORE THEN, GEOLOGISTS HAD FEW CLUES ABOUT HOW TO ESTABLISH CAUSAL RELATIONSHIPS BETWEEN THE THERMAL PROCESSES WITHIN THE EARTH'S INTERIOR AND ITS VISIBLE SURFACE FEATURES.

THE PLATE TECTONICS CONCEPT BEGINS IN THE UPPER MANTLE WHICH, THROUGH PARTIAL MELTING, GIVES RISE TO HOT MAGMA THAT THRUSTS ITSELF TO THE SURFACE AND COOLS TO FORM THE CRUST. AS NEW CRUST IS INTRODUCED FROM THE MANTLE, THE OLDER CRUST IS PUSHED ASIDE. AT THE SURFACE OF THE EARTH, THESE ZONES OF RISING MAGMA FORM A LONG, GLOBE-CIRCLING CHAIN OF VOLCANIC RIDGES, OR SPREADING CENTERS, MOST BUT NOT ALL OF WHICH PRESENTLY LIE IN THE OCEAN BASINS AT THE MID-OCEAN RIDGES.

FOR REASONS THAT ARE NOT COMPLETELY UNDERSTOOD, THE EARTH'S CRUST DOES NOT MOVE AS A SINGLE UNIT BUT IS BROKEN UP INTO MAJOR PLATES. AS THE PLATES MOVE, THEY CARRY NOT ONLY THE OCEANIC

CRUST BUT ALSO THE CONTINENTAL CRUST IN PIGGY-BACK FASHION ON TOP OF THE UPPER MANTLE. FOR EXAMPLE, THE AMERICAS ARE NOW SEEN AS HAVING BEEN JOINED TO EUROPE AND AFRICA UNTIL SEVERAL TENS OF MILLIONS OF YEARS AGO, WHEN A RIFT OR SPREADING CENTER SPLIT THEM ALONG WHAT IS NOW THE LINE OF THE MID-ATLANTIC RIDGE. SINCE THAT TIME, THE NEW AND OLD WORLDS HAVE BEEN MOVING APART AT A RATE OF 2 TO 4 CENTIMETERS PER YEAR, PRODUCING THE ATLANTIC OCEAN.

PLATE TECTONICS PROVIDES A PLAUSIBLE CAUSAL MECHANISM LINKING THE BIRTH OF THE OCEANIC CRUST AT THE SPREADING CENTERS TO ITS DEATH AT SUBDUCTION ZONES OR CONVERGENT MARGINS, WHEN TWO TECTONIC PLATES COLLIDE. SUCH COLLISIONS ARE AN INEVITABLE CONSEQUENCE OF THE CAUSAL MECHANISMS THAT CREATE THE PLATES IN THE FIRST PLACE AND DRIVE THEM AWAY FROM THE MID-OCEAN RIDGES. SINCE THE TOTAL SURFACE AREA OF THE EARTH IS FIXED, THE AGING EDGES OF A TECTONIC PLATE MUST ULTIMATELY ENCOUNTER THE EDGES OF ONE OR MORE OTHER PLATES. MOST OFTEN, WHEN THIS OCCURS, THE EDGE OF THE DENSER OF THE TWO PLATES DIVES -- OR IS SUBDUCTED -- BENEATH THE SECOND PLATE, CARRYING MOST OF THE CRUSTAL MATERIAL AND PERHAPS SOME OF ITS SEDIMENTARY COVER BACK INTO THE MANTLE. CONSIDERABLE HEAT APPEARS TO BE GENERATED AT THESE SUBDUCTION ZONES. IT SEEMS LIKELY THAT COMPLEX CHEMICAL REACTIONS OCCUR BETWEEN THE SUBDUCTING CRUST AND ITS SEDIMENTS AND THE OCEAN WATER. IF SO, THEY MAY RESULT IN THE DEPOSITION OF USEFUL MINERALS AT THE SUBDUCTION ZONE.

ONE OF THE EMPHASES IN THE FOUNDATION'S PLANS FOR ITS CRUSTAL RESEARCH ACTIVITIES IN FY 1984 AND SUCCEEDING YEARS WILL BE TO INCREASE UNDERSTANDING OF OCCURRENCES AT THE BOUNDARIES OF TECTONIC PLATES. THIS RESEARCH WILL BE PURSUED BY INVESTIGATORS IN DIFFERENT DISCIPLINES USING A VARIETY OF TECHNIQUES AND INSTRUMENTATION INCLUDING: SEISMIC TRANSECTS STARTING ON THE CONTINENT AND PROCEEDING TO THE OCEAN MARGINS; OBSERVATIONS OF

CRUSTAL STRUCTURES ON LAND; AND OCEAN DRILLING WHICH PROVIDES INFORMATION ON SUCH THINGS AS THE STRUCTURE OF SEDIMENTS AND ROCKS AS WELL AS THEIR MAGNETIC AND THERMAL CHARACTERISTICS.

AT THE VERY HOT SPREADING CENTERS THEMSELVES -- AS AT THE SUBDUCTION ZONES -- REACTIONS BETWEEN THE HOT, RISING MAGMA AND THE CHEMICAL-RICH SEA WATER COULD LEAD TO THE DEPOSITION OF USEFUL MINERALS IN THE CRUST. INDEED, OBSERVATIONS FROM THE SUBMERSIBLE *ALVIN* OF HYDROTHERMAL VENTS AT THE MID-ATLANTIC RIDGE HAVE PROVIDED TANTALIZING INDICATIONS ABOUT THE COMPLEXITY OF GEOTHERMAL AND GEOCHEMICAL PROCESSES THAT ACCOMPANY THE BIRTH OF THE OCEANIC CRUST. MORE RECENT INVESTIGATIONS FROM *ALVIN* AT SPREADING CENTERS IN THE PACIFIC HAVE REVEALED, IN ADDITION TO NEW GEOLOGICAL PHENOMENA, BIOLOGICAL COMMUNITIES LOCATED AT THE HYDROTHERMAL VENTS.

THESE VENT COMMUNITIES ARE THE ONLY MAJOR ECOSYSTEMS ON EARTH FUELED BY ENERGY-RICH SULFIDE COMPOUNDS. CHEMOSYNTHETIC BACTERIA, INDEPENDENT OF SUNLIGHT THAT POWERS THE REST OF THE WORLD'S BIOTA, ARE THE FOOD CHAIN BASE FOR A DIVERSE GROUP OF UNIQUE AND PREVIOUSLY UNKNOWN ORGANISMS. THE INITIAL DISCOVERY OF THESE STRANGE BIOLOGICAL COMMUNITIES WAS AN UNANTICIPATED RESULT OF A FIELD TRIP TO STUDY THE GEOLOGY OF THE SPREADING CENTER.

Since full elucidation of the plate tectonics concept requires integration of the data gathered from many different parts of the earth, a good deal of scientific activity during the past twenty years has been international in character. The plate tectonics concept itself was established during the Upper Mantle Project of the 1960s, sponsored by the International Union of Geodesy and Geophysics. The International Decade of Ocean Exploration, ending in 1980, involved 52 nations. Many large projects undertaken during that decade were made possible only because several countries pooled their scientists, equipment and ships. A new international research program for the 1980s, the Inter-Union Lithosphere Program, has been initiated in recognition of the consensus among earth and ocean scientists that the time is now ripe for a concerted multi-disciplinary attack upon the evolution and dynamics of the earth's lithosphere, or crust.

PLANNING, BUDGETING AND MODES OF SUPPORT

The Foundation support for research in the astronomical, atmospheric, earth and ocean sciences is provided in four dominant modes: direct support to individual investigators to cover such costs as developing instruments required for their experiments, data analysis, and post-doctoral and graduate research assistants; support of National centers and other major research facilities; support for large coordinated projects; and indirect support of many investigators who are given access to facilities, data, or samples on a competitive basis.

The major facilities which the Foundation supports in these disciplines include:

- five user-oriented National astronomical observatories plus partial support of a half dozen university observatories that operate a range of radio telescopes;
- a longitudinal chain of back scatter radars to observe winds and other phenomena in the upper atmosphere at locations from Greenland to Peru;
- the National Center for Atmospheric Research (NCAR) which both conducts staff research itself and provides major computational and modelling facilities, aircraft, and radars to university researchers;
- seismic reflection profiling by the Consortium for Continental Reflection Profiling (COCORP) to map the structure of the continental crust to a depth of 70 kilometers;
- the ocean drilling ship Challenger and associated core repositories and geophysical data banks;
- with NOAA and the Office of Naval Research, the manned submersible Alvin; and
- the bulk of the operations of 22 of the 25 ships currently constituting the academic oceanographic fleet.

Individual project support is also provided in all of these scientific disciplines, though the proportions vary from field to field. In the earth sciences program, for example, the bulk of the funding is for small awards to individual investigators. In contrast, over two-thirds of the budget for the astronomy program goes to the National observatories and the university observatories. Large coordinated experiments are supported, particularly in the atmospheric and ocean sciences, that involve large numbers of investigators and facilities. The balance between facilities development, operation and maintenance, and project grants is carefully examined each year by the NSF staff with advice from their scientific advisory committees. The National Science Board also reviews each of these programs from time to time and examines the balance among their various activities and modes of support.

Access to facilities and coordination of their scientific use is accomplished in different ways in these disciplines. For example, in the earth sciences, the consortium members determine where particular seismic surveys of the continental crust will be conducted. Individual grantees may very well propose research either in the area where the survey is to be conducted or where such work has already been carried out. Decisions on their proposals are made by the normal competitive peer review process of the program.

In the case of NCAR, proposals from individual investigators include a statement on the facilities to be used, e.g., radar or aircraft. They are reviewed by a user coordinating committee which will fit them into the schedule. Use of the facilities is without charge to NSF grantees, the cost having been included in the general support contract which NSF gives to NCAR. The University National Oceanographic Laboratory System (UNOLS)

PERFORMS A SIMILAR REVIEW FUNCTION IN THE OCEANOGRAPHIC RESEARCH PROGRAM, REVIEWING PROPOSALS AND DETERMINING THEIR PRIORITY AND SCHEDULE ON ONE OF THE SHIPS OF THE ACADEMIC FLEET.

IN THE CASE OF THE NATIONAL ASTRONOMY CENTERS, INVESTIGATORS SUBMIT PROPOSALS FOR OBSERVATIONS DIRECTLY TO THE APPROPRIATE CENTER. THESE ARE REVIEWED, SELECTED AND SCHEDULED BY A USER PEER REVIEW COMMITTEE. AGAIN, TIME ON THE FACILITY IS FREE TO THOSE SELECTED AND, IN ADDITION, MOST TRAVEL COSTS ARE COVERED BY THE CENTERS AS WELL.

THESE FACILITIES MAKE POSSIBLE A LARGE NUMBER OF INDIVIDUAL PROJECTS. FOR EXAMPLE, WELL OVER 1,000 ASTRONOMERS USE THE NATIONAL OBSERVATORIES EACH YEAR FOR THEIR PROJECTS. SIMILARLY, DEEP SEA CORES FROM THE CHALLENGER PROGRAM ARE REQUESTED AND USED BY LARGE NUMBERS OF MARINE GEOLOGISTS AND GEOPHYSICISTS.

OVER THE YEARS, THE HOUSE SCIENCE AND TECHNOLOGY COMMITTEE HAS TAKEN THE LEADERSHIP IN RECOGNIZING SOME OF THE QUESTIONS WHICH SHOULD BE ADDRESSED IN BUDGETING FOR AND MANAGING COMPLEX ACTIVITIES SUCH AS THESE.

WITHIN THE FRAMEWORK OF A POLICY STATEMENT ADOPTED BY THE NATIONAL SCIENCE BOARD IN 1979, IN RESPONSE TO A RECOMMENDATION FROM YOUR COMMITTEE, THESE QUESTIONS -- THE APPROPRIATE BALANCE BETWEEN LARGE FACILITIES AND SUPPORT TO INDIVIDUALS AND THE MECHANISM FOR INITIATING NEW, LARGE-SCALE PROJECTS; AS WELL AS THE ADEQUACY OF SUPPORT FOR EXISTING FACILITIES AND THE PHASING OUT OR REPLACEMENT OF EXISTING FACILITIES -- ARE ADDRESSED AT SEVERAL DIFFERENT LEVELS WITHIN THE FOUNDATION AS A PART OF ITS PLANNING AND BUDGETING PROCESS. AS I HAVE MENTIONED ALREADY, THEY ARE ADDRESSED BY THE NSF STAFF AND ITS SCIENTIFIC ADVISORY PANELS. THEY ARE ALSO REVIEWED BY THE NATIONAL SCIENCE BOARD AND

BY ME. IN ADDITION, WHEN WE ANTICIPATE THE INITIATION OF MAJOR NEW FACILITIES OR THE PHASING OUT OF MAJOR EXISTING FACILITIES, THEY ARE CLOSELY REVIEWED BY THE OFFICE OF MANAGEMENT AND BUDGET AND THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY BEFORE BEING SUBMITTED TO THE CONGRESS.

HIGHLIGHTS OF NSF'S FY 1984 PROGRAM

I AM PLEASED THAT WE ARE PROPOSING AN INCREASE OF 21.3 PERCENT IN THE LEVEL OF SUPPORT FOR ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES IN FY 1984. WE ARE PLANNING A MAJOR EMPHASIS ON THE ASTRONOMICAL SCIENCES WHICH WILL RECEIVE A 25.9 PERCENT INCREASE IN THIS RAPIDLY ADVANCING AND SCIENTIFICALLY EXCITING AREA. THE INCREASE WILL ALLOW US TO UPGRADE INSTRUMENTATION AT UNIVERSITY AND NATIONAL OBSERVATORIES AND TO SUPPORT PRELIMINARY DESIGN STUDIES FOR THE VERY LONG BASELINE ARRAY (VLBA). THE VLBA IF CONSTRUCTED WOULD BE A MAJOR, NEW RADIO TELESCOPE THAT WAS GIVEN VERY HIGH PRIORITY IN THE RECENT REPORT OF THE ASTRONOMY SURVEY COMMITTEE OF THE NATIONAL ACADEMY OF SCIENCES. IT WOULD PROVIDE 100 TIMES GREATER RESOLUTION OF CELESTIAL OBJECTS THAN THE BEST PRESENT TELESCOPES. THE DESIGN STUDIES TO BE SUPPORTED IN 1984 WOULD PROVIDE REALISTIC COST ESTIMATES AND OTHER INFORMATION NECESSARY FOR CONSIDERING THE INITIATION OF THIS PROJECT IN FUTURE BUDGETS.

THE EMPHASIS ON EARTH SCIENCES IN THE LAST FEW FOUNDATION BUDGETS IS CONTINUED IN FY 1984. THE INCREASE WILL ALLOW YEAR-ROUND, CONTINENTAL REFLECTION PROFILING OPERATIONS AND GENERAL UPGRADING OF MUCH OF THE RESEARCH INSTRUMENTATION WHICH HAS BECOME OBSOLETE SINCE THE MAJOR FEDERAL EQUIPMENT INVESTMENTS OF THE 1960s.

In FY 1984, the Foundation expects to invest about $68.0 million to support crustal research, as already discussed. Included in this is $26.3 million for the Ocean Drilling Program, which is now in the AAEO activity and which provides funds adequate to continue the Deep Sea Drilling. A distinguished committee of earth and ocean scientists has reviewed priorities and directions for crustal research. Their recommendation, not yet published, is to continue ocean drilling, preferably with a large, modern, leased commercial drill ship. This preliminary recommendation is under review by the Foundation. If the Foundation and the Administration concur with it, we will expect to present appropriate program recommendations to the Congress.

CONCLUDING REMARKS

Mr. Chairman, I hope my remarks this afternoon have conveyed a sense of the great excitement of science and scientific research to you and to the other members of the Committee.

I am extremely pleased that the President's Budget Request for the Foundation proposes an 18.3 percent increase over FY 1983 for the support of basic research. In the sciences we have been discussing today, this increase will allow us to upgrade instrumentation for astronomical and geological research, expand our support of graduate student research assistants and research post-doctorates, expand our activities in the exciting area of crustal research, initiate design studies of a major new astronomical facility, and maintain the level of our core programs and activities. These are investments in our Nation's scientific and technical future which I hope this Committee will strongly endorse.

NSF OBLIGATIONS BY BUDGET ACTIVITY
FY 1983-1984
(DOLLARS IN MILLIONS)

BUDGET ACTIVITY	FY 1983	FY 1984	% CHANGE FY 84/83
MATHEMATICAL AND PHYSICAL SCIENCES	$299.7	$364.3	21.5%
ENGINEERING	100.8	123.0	22.0%
BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES	190.2	223.6	17.5%
ASTRONOMICAL, ATMOSPHERIC, EARTH, AND OCEAN SCIENCES	276.2	334.9	21.3%
U.S. ANTARCTIC PROGRAM	83.2	102.1	22.7%
SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS	44.2	36.8	-16.7%
PROGRAM DEVELOPMENT AND MANAGEMENT	65.3	66.0	1.1%
UNDISTRIBUTED	4.5	.0	-100.0%
SUBTOTAL, RESEARCH & RELATED ACTIVITIES	1,064.1	1,250.7	17.5%
SCIENCE AND ENGINEERING EDUCATION	30.0	39.0	30.0%
SPECIAL FOREIGN CURRENCY	3.1	2.6	-16.6%
TOTAL	$1,097.2	$1,292.3	17.8%

O/D 83-509
1 29 83

ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
ASTRONOMICAL SCIENCES	$63.0	$79.3	25.9%
ATMOSPHERIC SCIENCES	75.1	90.6	20.7%
EARTH SCIENCES	34.1	42.1	23.5%
OCEAN SCIENCES OCEAN DRILLING PROGRAM	97.7	115.4	18.1%
ARCTIC RESEARCH PROGRAM	6.3	7.5	19.0%
TOTAL	$276.2	$334.9	21.3%

O/D 83 513
1 29 83

CRUSTAL RESEARCH
FY 1983-1984
(DOLLARS IN MILLIONS)

	FY 1983	FY 1984	% CHANGE FY 84/83
EARTH SCIENCES			
CORE PROGRAM	$21.1	$24.8	17.5%
MAJOR PROJECTS (E.G., COCORP)	4.0	6.3	57.5%
SUBMARINE GEOLOGY AND GEOPHYSICS	8.9	10.4	15.9%
OCEAN DRILLING	16.5	26.3	59.4%
TOTAL	$50.5	$67.8	34.3%

O/D 83-524
1-31-83

ASTRONOMICAL, ATMOSPHERIC, EARTH, AND OCEAN SCIENCES

PROGRAM ACTIVITY SUMMARY

FY 1984 PROGRAM TOTAL $334,900,000

	Subactivity	Actual FY 1982	Request FY 1983	Current Plan FY 1983	Estimate FY 1984	Difference FY 1984/83
I	Astronomical Sciences	$59,097,388	$63,200,000	$62,983,000	$79,300,000	$16,317,000
II	Atmospheric Sciences	70,338,523	74,800,000	75,050,000	90,600,000	15,550,000
III	Earth Sciences	29,489,377	34,400,000	34,100,000	42,100,000	8,000,000
IV	Ocean Sciences	75,030,070	81,000,000	81,176,368[1]	89,100,000	7,923,632
V	Ocean Drilling Programs	20,000,000	14,000,000	16,500,000	26,300,000	9,800,000
VI	Arctic Research Program	5,897,498	6,300,000	6,300,000	7,500,000	1,200,000
	Total	$259,852,856	$273,700,000	$276,109,368	$334,900,000	$58,790,632

[1] Includes $776,368 carryover funds from FY 1982.

	Change FY 1984/FY 1983 ($ Millions)	Percentage
Astronomical Sciences	$16.3	25.9%
Atmospheric Sciences	15.6	20.7
Earth Sciences	8.0	23.5
Ocean Sciences	7.9	9.8
Ocean Drilling Programs	9.8	59.4
Arctic Research	1.2	19.0
Total	$58.8	21.3%

Changes in individual subactivities:

- Astronomy is increased $16,317,000 from $62,983,000 to $79,300,000. This increase allows the subactivity to begin to carry out the most important recommendations of the report of Astronomy Survey Committee of the National Academy of Sciences. This includes addressing "prerequisites" such as improved instrumentation at universities and national centers, and design studies on the Very Long Baseline Array (VLBA).

- Atmospheric Sciences is increased $15,550,000 from $75,050,000 to $90,600,000. This increase supports further upgrading of the computing facility at the National Center for Atmospheric Research with the purchase of a new mass storage system. Project support increases in all subdisciplines particularly in atmospheric chemistry. The Global Atmospheric Research Program now well into the data analysis phase continues to phase down.

- Earth Sciences is increased $8,000,000 from $34,100,000 to $42,100,000 which allows year-round continental reflection profiling (COCORP) operations, major upgrading of instrumentation and a major research thrust on the evolution and structure of the continental crust.

- Ocean Sciences is increased $7,923,632 from $81,176,368 to $89,100,000 with emphasis on crustal studies, particularly work related to the continental thrust in the Earth Science subactivity. Increased equipment support is provided through project grants. Maintenance and upgrading of shipboard scientific equipment is also a priority.

- Ocean Drilling is increased by $9.8 million, from $16,500,000 to $26,300,000. The Foundation is reviewing the Ocean Drilling Program in the larger context of crustal studies and in the integration of continental and marine geology and geophysical studies. Pending the outcome of this study, the budget has been set at a level which will provide for the continuation of the Deep Sea Drilling Project and for program activities that are currently being examined.

- Arctic Research is increased $1,200,000 from $6,300,000 to $7,500,000 with emphasis on studies of arctic glaciers.

Changes in Budget Structure

Ocean Drilling Programs This former activity is now included in the AAEOS activity to facilitate budgetary comparisons and coordination of program development with closely related portions of that activity, particularly submarine geology and geophysics.

A study is being undertaken at the request of the Foundation by a committee composed of leaders in the earth and ocean sciences communities to assess priorities in crustal studies. Special attention will be devoted to ocean drilling and the most effective means to meet needs in the area. Their report together with the Foundation's recommendations based on it will be available for consideration as part of the Congressional review of the FY 1984 Budget.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

nsf

OFFICE OF SCIENTIFIC
OCEAN DRILLING

FEB 2 - 1983

MEMORANDUM

TO: Members of the *Ad hoc* Advisory Group on Crustal Studies

FROM: Director, Office of Scientific Ocean Drilling

SUBJECT: Proposed Use of a Commercial Drillship in the Advanced Ocean Drilling Program (AODP).

I. Summary

In recent months the market for large modern drillships has changed dramatically. Information provided by Sedco, Inc., on the SEDCO 472 enables the NSF to present data on the capability and cost of a commercially available drillship that can be compared to the EXPLORER and CHALLENGER options. It should be noted that if the Foundation determines that a drillship similar to SEDCO 472 should be leased for use in the AODP, a competitive procurement would be conducted to select the most effective ship at the least cost. Therefore, the material presented in this memorandum should be considered to illustrate the possibilities and not to represent a selection of the SEDCO 472.

Sedco, Inc., has advised NSF that the SEDCO 472 could be operated, on a long term basis, at a day rate less than half that which the ship commanded until September 1982. Other large dynamically positioned drillships may be available at similar rates. The projected operating cost is essentially the same as the current cost of CHALLENGER, with a required capital investment not greater than that necessary to refurbish CHALLENGER.

The SEDCO 472 and other large drillships offer technical capabilities well beyond CHALLENGER's in every area. Their capabilities are somewhat less than EXPLORER's in most areas, but some offer immediate access to a deep water riser, which EXPLORER cannot offer in the first-stage conversion. These ships generally have adequate accommodations for increased international participation, but lack the room for future expansion offered by EXPLORER. Laboratory space could be approximately double that on CHALLENGER, but only about half that available on EXPLORER.

Given the recently changed market conditions for these ships, selection of one of them as the drilling platform for the AODP appears likely to be the most cost-effective option available.

Relative capabilities of the three ships. [Source: National Science Foundation]

	Challenger	*Sedco 472*	*Explorer*
Length	400 feet	470 feet	617 feet
Operating displacement	10,600 tons	16,700 tons	44,400 tons
Installed power	7,700 kilowatts	14,700 kilowatts	27,500 kilowatts
Scientific party	29	50	50
Drill string	23,000 feet	30,000 feet	33,000 feet
Mud-cement systems	Limited	Good	Good
Casing storage	Limited	Good	Unlimited
Riser and blowout preventer	No	6,000 feet+	Maybe someday
Weather limits for drilling	Less than other ships but not precisely known	45-knot wind, 15-foot seas, 2.5-knot current	45-knot wind, 15-foot seas, 2.5-knot current
Sea keeping	Good	Good+	Excellent
High-latitude capability	Fair	Fair to good	Good
Laboratory space	4,500 square feet	9,000 square feet	19,000 square feet
Operating budget estimate	\$53,000 per day	\$53,000 per day	\$57,000 per day
Capital investment	\$11 million	\$10 million	\$90 million

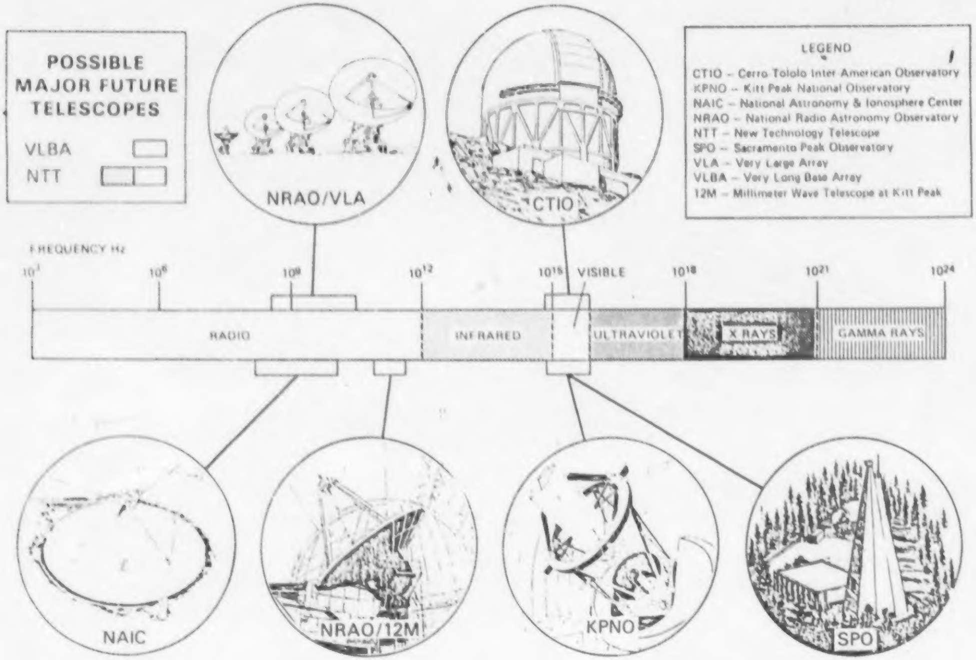
Science Magazine
Feb 24, 1983

TABLE 2.1 Requirements for New Funding

PREREQUISITES FOR NEW RESEARCH INITIATIVES	(Millions of 1980 Dollars)
A. Instrumentation and detectors (doubling of present $15 million/year level of effort by increments over 10 years)	$ 75
B. Theory and data analysis (augmentation by $5 million/year)	50
C. Computational facilities (30 minicomputer systems installed at a rate of 5 systems/year, including operations)	20
D. Laboratory astrophysics (augmentation by $2.5 million/year)	25
E. Technical support at ground-based observatories, including 40 new support positions	20
DECADE TOTAL, PREREQUISITES	$190
NEW PROGRAMS	
A. *Major New Programs* In order of priority:	
1. Advanced X-Ray Astrophysics Facility (AXAF)	$500
2. Very-Long-Baseline (VLB) Array (including $15 million for operations)	50
3. New Technology Telescope (NTT)	100
4. Large Deployable Reflector in space	300
Decade Subtotal	$950
B. *Moderate New Programs* In rough order of priority:	
1. Augmentation to Explorer satellite program	$200
2. Far-ultraviolet spectrograph in space	150
3. Space VLB interferometry antenna	60
4. Optical/infrared telescopes in the 2-5-m class	20
5. Advanced Solar Observatory in space	200
6. Cosmic-ray experiments	100
7. An astronomical Search for Extraterrestrial Intelligence (SETI)	20
Decade Subtotal	$750
C. *Small New Programs* Of highest priority:	
• 10-m submillimeter-wave radio antenna (including $2 million for operations)	$ 4
Other important programs:	
• Spatial interferometer for the mid-infrared (including $1 million for operations)	3
• High-precision optical astrometry program	3
• Temporary program to maintain scientific expertise at U.S. universities	10
Decade Subtotal	$ 20
DECADE TOTAL, NEW PROGRAMS	$1,720

From
Astronomy and Astrophysics for the 80's
National Academy of Sciences
1982

SPECTRUM COVERAGE OF TELESCOPES AT NATIONAL ASTRONOMY CENTERS


POSSIBLE MAJOR FUTURE TELESCOPES
VLBA
NTT
NRAO/VLA
CTIO
LEGEND
CTIO – Cerro Tololo Inter American Observatory
KPNO – Kitt Peak National Observatory
NAIC – National Astronomy & Ionosphere Center
NRAO – National Radio Astronomy Observatory
NTT – New Technology Telescope
SPO – Sacramento Peak Observatory
VLA – Very Large Array
VLBA – Very Long Base Array
12M – Millimeter Wave Telescope at Kitt Peak
FREQUENCY Hz
10^3
10^6
10^9
10^{12}
10^{15}
VISIBLE
10^{18}
10^{21}
10^{24}
RADIO
INFRARED
ULTRAVIOLET
X RAYS
GAMMA RAYS
NAIC
NRAO/12M
KPNO
SPO

The Astronomy Survey Committee recommends the approval and funding of new programs in astronomy and astrophysics for the 1980's. These have been arranged into three categories according to the scale of resources required.

A. *Major New Programs* The Committee believes that four major programs are critically important for the rapid and effective progress of astronomical research in the 1980's and is unanimous in recommending the following order of priority:

1. *An Advanced X-Ray Astrophysics Facility* (AXAF) operated as a permanent national observatory in space, to provide x-ray pictures of the Universe comparable in depth and detail with those of the most advanced optical and radio telescopes. Continuing the remarkable development of x-ray technology applied to astronomy during the 1970's, this facility will combine greatly improved angular and spectral resolution with a sensitivity up to one hundred times greater than that of any previous x-ray mission.
2. *A Very-Long-Baseline* (VLB) *Array* of radio telescopes designed to produce radio images with an angular resolution of 0.3 milliarcsecond. Among many potential applications of profound importance, this instrument will probe the small-scale structure surrounding the enigmatic energy sources in the cores of quasars and active galactic nuclei and will directly determine the distance scale within our Galaxy with unprecedented accuracy.
3. *A New Technology Telescope* (NTT) of the 15-m class operating from the ground at wavelengths of 0.3 to 20 μm, to provide a tenfold increase in light-gathering capacity at visual wavelengths and a hundredfold increase in speed for spectroscopy at infrared wavelengths, with application to a very wide range of scientific problems. The Committee finds the scientific merit of this instrument to be as high as that of any other facility considered and emphasizes that its priority ranking does not reflect its scientific importance but rather its state of technological readiness. *The design studies needed before NTT can be constructed are of the highest priority and should be undertaken immediately.*
4. *A Large Deployable Reflector* in space, to carry out spectroscopic and imaging observations in the far-infrared and submillimeter wavelength regions of the spectrum that are inaccessible to study from the ground, thus extending the powerful capabilities of NTT to these longer wavelengths. Such an instrument, in the 10-m class, will present unprecedented opportunities for studying molecular and atomic processes that accompany the formation of stars and planetary systems.

B. *Moderate New Programs* In rough order of priority, these are:

1. *An augmentation to the NASA Explorer program*, which remains a flexible and highly cost-effective means to pursue important new space-science opportunities covering a wide range of objects and nearly every region of the electromagnetic spectrum.
2. *A far-ultraviolet spectrograph in space*, to carry out a thorough study of the 900–1200-Å region of the spectrum, important for studies of stellar evolution, the interstellar medium, and planetary atmospheres.
3. *A space VLB interferometry antenna* in low-Earth orbit, to extend the powerful VLBI technique into space in parallel with the rapid completion of a ground-based VLB Array, in order to provide more detailed radio maps of complex sources, greater sky coverage, and higher time resolution than the Array can provide alone.
4. *The construction of optical/infrared telescopes in the 2–5-m class* to observe transient phenomena, conduct long-term survey and surveillance programs, provide crucially needed ground-based support to space astronomy, and permit the development of instrumentation under realistic observing conditions. The Committee particularly encourages federal assistance for those projects that will also receive significant nonfederal funding for construction and operation.
5. *An Advanced Solar Observatory* in space, to provide observations of our Sun—the nearest star—simultaneously at optical, extreme ultraviolet, gamma-ray, and x-ray wavelengths, to carry out long-term studies of large-scale circulation, internal dynamics, high-energy transient phenomena, and coronal evolution.
6. *A series of cosmic-ray experiments* in space, to promote the study of solar and stellar activity, the interstellar medium, the origin of the elements, and violent solar and cosmic processes.
7. *An astronomical Search for Extraterrestrial Intelligence* (SETI), supported at a modest level, undertaken as a long-term effort rather than as a short-term project, and open to the participation of the general scientific community.

C. *Small New Programs* The program of highest priority is:

- An antenna approximately 10 m in diameter for submillimeter-wave observations, at an excellent ground-based site.

ASTRONOMY AND ASTROPHYSICS FOR THE 1980's
NAS, 1982

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Mr. **Walgren**. Thank you very much, Dr. Knapp.

The ocean drilling program has been relatively controversial with this committee for the time that I have served on it and certainly is one that we want to pay very close oversight attention to.

Now, I understand in the budget that you are submitting that we have a $9.8 million increase attributable to the ending of agreements with our foreign partners so that no funds for drilling beyond the current fiscal year.

At the same time, it is my understanding that last year's budget indicated that the deep sea drilling program would complete its field operations in 1983.

So I guess the question is, how are we continuing this program? Apparently we are extending the operations with the ship *Challenger*. Is that correct?

Dr. **Knapp**. Dr. Drake will talk to you in some detail about the work of the committee he chaired. I asked the committee to look at the problem of crustal research and the priorities within crustal research, particularly those priorities associated with the ocean drilling program.

When I came to the Foundation as Director, the scientific drilling program was controversial. However, at the present time, I believe this committee will make a recommendation affecting the *Challenger* in the following way:

The *Challenger* program for drilling was expected to be completed in fiscal year 1983. At that time, if drilling with the *Challenger* were to be continued, the ship would be laid up, be repaired, and refurbished for further use.

The end of that drilling will now occur 1 or 2 months into fiscal year 1984. Even if the *Challenger* were continued, as a drill ship, the drilling would cease so that the ship could be refurbished.

The increase in funds is to cover either (1) the refurbishment of the *Challenger*, (2) the modification of the *Explorer* to be a larger drill ship, or (3) the use of a third platform for ocean drilling. In this case, the third platform could be a ship leased from the ships being built for oil exploration.

We are in a fortunate situation, as has been discovered by this committee. The world oil market is depressed, and six such ships suitable for deep ocean drilling would be available for a contractor to the Foundation to lease for deep ocean drilling and to continue the crustal studies program.

This is a fortunate occurrence. Six to nine months ago, these ships would not have been available or would have been available at a much higher cost. All of these complex interrelations are being evaluated at the Foundation right now. As I said, we will come to you with a proposal to go forward with ocean drilling. There is no question of NSF's commitment to ocean drilling.

The proposal will be the most cost effective for the maximum scientific output that we can achieve with the funds at NSF's disposal in the crustal studies program. It is a program of utmost importance; one that must go forward.

Mr. **Walgren**. If we do go forward in a leased, different ship than the *Explorer*, how do we explain the $15 million that has been spent on the *Explorer*?

Dr. **Knapp**. The $15 million and $5 million from industrial partners in the earlier OMD effort have been expended on a series of scientific programs. The funds have been used for a series of scientific instrumentation development programs and two different designs. One design used the *Explorer* in a riser configuration for margin drilling, in conjunction with commercial partners. The other design for modification of the *Explorer* which would have used the ship in the drilling program without a riser.

These expenditures were necessary for NSF to understand the science and costs necessary to convert the *Explorer*. The capital cost to complete the conversion of *Explorer* is now estimated at $90 million.

I, and most of the people in the Foundation and in the oceanographic and earth sciences scientific community, feel that this expenditure to understand accurately the costs involved and the necessary modifications to the ship is money certainly not misspent. It is necessary many times to develop complete plans in order to understand the liabilities to be incurred in any program of this magnitude.

Mr. **Walgren**. I see.

Dr. **Knapp**. Perhaps I could ask Dr. Shinn, the Director of the Office of Scientific Ocean Drilling, if he would concur with these remarks or have anything to add.

Mr. **Walgren**. I think that would be helpful.

Dr. Shinn.

Dr. **Shinn**. Yes, sir, the total amount we spent was about $21.5 million. That included just a little over $5 million contributed by oil companies under the ocean margin drilling program. Of that, about a third was spent on scientific planning, independent of the choice of ship. The work accomplished under those expenditures is entirely useful under the options we are pursuing now.

The remainder was spent on engineering design studies for the *Explorer*. If, as now appears to be the case, the intelligent thing to do is not to go ahead with the *Explorer*, I think we simply have to accept that as the cost of making the decision.

Mr. **Walgren**. Perhaps we ought to leave the record open for some submissions as to why, at this point, it is the intelligent thing not to go forward with the *Explorer*, and perhaps Dr. Drake will touch on some of those considerations, but it is a matter, of course, of concern for the committee, and we want to have a record that completely documents what has happened there and how it is to be understood.

[Material to be supplied follows:]

MATERIAL FOR THE RECORD: With Respect to the Selection of a Drillship for the Advanced Ocean Drilling Program

Dr. Drake's testimony on the findings of the *Ad hoc* Advisory Group on Crustal Studies, which he chaired, explains the basic rationale for the Foundation's preference for leasing a commercial drillship rather than proceeding with EXPLORER conversion at this time.

Because of worldwide conditions in the oil market, prices in the offshore exploration industry are temporarily depressed. A long-term lease for a modern dynamically-positioned drillship could probably be negotiated, under current economic conditions, for about one-half the going rate for such ships even a few months ago.

A commercial ship would require only limited conversion to add laboratory spaces and prepare the drill rig for scientific operations, and would offer the possibility of future drilling with riser and blowout preventors without additional capital costs. When contrasted with estimates of capital costs of $80-90 million for a first-stage riserless conversion of EXPLORER, this option is extremely attractive. Operating costs for the two ships would be comparable.

Three backup documents are provided for the record:

- Memorandum dated February 2, 1983, "Proposed Use of a Commercial Drillship in the Advanced Ocean Drilling Program (AODP)."
- "Budget Summary of Basic Drillship Options," dated January 31, 1983.
- A tabular comparison of scientific capabilities of CHALLENGER, EXPLORER, and a large commercial drillship, undated.

These three documents were prepared for the *Ad hoc* Advisory Group on Crustal Studies, which met on February 3-4, 1983.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

nsf

OFFICE OF SCIENTIFIC
OCEAN DRILLING

FEB 2 - 1983

MEMORANDUM

TO: Members of the Ad hoc Advisory Group on Crustal Studies

FROM: Director, Office of Scientific Ocean Drilling

SUBJECT: Proposed Use of a Commercial Drillship in the Advanced Ocean Drilling Program (AODP).

I. Summary

In recent months the market for large modern drillships has changed dramatically. Information provided by Sedco, Inc., on the SEDCO 472 enables the NSF to present data on the capability and cost of a commercially available drillship that can be compared to the EXPLORER and CHALLENGER options. It should be noted that if the Foundation determines that a drillship similar to SEDCO 472 should be leased for use in the AODP, a competitive procurement would be conducted to select the most effective ship at the least cost. Therefore, the material presented in this memorandum should be considered to illustrate the possibilities and not to represent a selection of the SEDCO 472.

Sedco, Inc., has advised NSF that the SEDCO 472 could be operated, on a long term basis, at a day rate less than half that which the ship commanded until September 1982. Other large dynamically positioned drillships may be available at similar rates. The projected operating cost is essentially the same as the current cost of CHALLENGER, with a required capital investment not greater than that necessary to refurbish CHALLENGER.

The SEDCO 472 and other large drillships offer technical capabilities well beyond CHALLENGER's in every area. Their capabilities are somewhat less than EXPLORER's in most areas, but some offer immediate access to a deep water riser, which EXPLORER cannot offer in the first-stage conversion. These ships generally have adequate accommodations for increased international participation, but lack the room for future expansion offered by EXPLORER. Laboratory space could be approximately double that on CHALLENGER, but only about half that available on EXPLORER.

Given the recently changed market conditions for these ships, selection of one of them as the drilling platform for the AODP appears likely to be the most cost-effective option available.

II. Technical Summary

The SEDCO 472 is one of six existing drillships which have actually drilled successfully in over 2,000 feet of water, with a riser and well control equipment, while dynamically positioned. Three of these six ships are owned by Sedco, two others are United States owned, and the sixth is French. Another six to eight ships arguably have the capability to work in deep water while dynamically positioned, but are untested. The larger of these ships would all be generally capable, if suitably modified, of carrying out most of the objectives of the AODP, as described in the COSOD report and other documents.

The technical characteristics and estimated costs of the SEDCO 472 have been provided to NSF by Sedco, Inc., which has agreed to the use of their information in this memorandum. In some cases the data given herein are modifications of data provided by Sedco, or are drawn entirely from other sources.

Principal dimensions and characteristics of the CHALLENGER, EXPLORER, and SEDCO 472 are as follows:

	CHALLENGER	SEDCO 472	EXPLORER
Length	400 ft	470 ft	617 ft
Beam	65 ft	70 ft	116 ft
Operating Draft	22 ft	25 ft	30 ft
Operating Displacement	10,600 tons	16,700 tons	44,400 tons
Installed Power	7,700 KW	14,700 KW	27,500 KW
Speed	12 kts	14 kts	10 kts
Crew	45	55	55
Scientific Party	29	50	50
Quarters	74	116	150
Liveability	poor	fair-good	excellent

In general, the SEDCO 472 is about 60 percent larger than CHALLENGER, but less than half the size of EXPLORER. Its size offers a significant advantage in accommodations and carrying capacity over CHALLENGER, but does not allow the really excellent laboratory arrangements possible on EXPLORER, or the greatly improved living space and the capacity for future growth possible on EXPLORER.

Characteristics of the three ships which affect their ability to drill the more difficult scientific targets may be summarized as follows:

	CHALLENGER	SEDCO 472	EXPLORER
Drill String	23,000 ft	30,000 ft	33,000 ft
Heave Compensation	good	good	good
Mud/Cement Systems	limited	good	good
Casing Storage	limited	good	unlimited
Riser & BOP	no	6,000 ft+	maybe someday
Weather Limits for Drilling	less than other ships, but not precisely known	45 kts wind 15/26 ft seas 2.5 kt current	45 kts wind 15/26 ft seas 2.5 kt current
Sea Keeping	good	good+	excellent
High Latitude Capability	fair	fair-good	good
Laboratory Space	4,500 ft^2	9,000 ft^2	19,000 ft^2

Drill String: The capacities given are those which can be conveniently handled, and thus used in normal drilling. Additional pipe can be carried in the hold in all three ships, but cannot be used in drilling without a prohibitive handling time penalty. Usable drill string length is also a function of drill string design. The SY 135 pipe currently in use has a practical limit of about 25,000 feet. An improved design with heavier pipe at the top of the string would extend this limit to about 30,000 feet. Beyond this depth some aluminum pipe would have to be used to reduce the total string weight.

Heave Compensation: A new large capacity heave compensator is included in the modification plans for each ship. Heave compensation cannot be used at certain critical points, however, so the inherently lesser heave characteristics of the larger ships offer an advantage.

Mud/Cement Systems: In riserless drilling mud is used sporadically to keep the hole clean and lubricate the bit. Since it cannot be recovered, its use is limited by the carrying capacity of the ship, as well as by cost. CHALLENGER's carrying capacity is quite limited; the other ships are not.

Casing: Carrying capacity on CHALLENGER is limited to about 2,500 feet. Carrying capacities of the other ships are essentially unlimited in riserless operations. Use of casing can greatly assist penetration in some drilling conditions.

Riser and Blowout Preventer (BOP): CHALLENGER cannot carry or handle a riser and BOP. EXPLORER has been designed to carry a 13,000-foot riser, but the expense of such equipment is at present prohibitive, and it is not included in the current conversion plans.

The SEDCO 472 can presently store 4,300 feet of riser, and can handle risers to at least 6,000 feet. Sedco claims this capability could be extended to 10,000 feet without major modification, but this claim is unproven. The existing capability would be decreased somewhat by the need to install laboratories in space now used for tubular storage. Thus as configured for scientific drilling the SEDCO 472 could deploy a riser to depths of interest for some important scientific targets, but not without the use of a second vessel to carry the riser and many other supplies. Such a vessel could be leased on a short term basis. The costs of riser drilling to deep depths would be 50-100 percent greater, on a daily basis, than the costs of riserless drilling. Weather would also impose a limit on the ability to transfer large pieces of equipment between ships. Despite these limits, the riser capability of the SEDCO 472 is a significant advantage over either CHALLENGER or EXPLORER, and will allow drilling some deep passive margin holes that otherwise could not be attempted without the major expense of equipping EXPLORER with a riser. In the long run, however, a ship with EXPLORER's full capabilities will undoubtedly be required if the most difficult targets are to be attempted.

Weather Limits and Sea Keeping: Both SEDCO 472 and EXPLORER have been designed to drill normally in winds to 45 knots, 15-foot significant seas, and surface currents to 2.5 knots. CHALLENGER's limits are somewhat less than these, but not precisely known. High winds and currents require high power to maintain station; in this the SEDCO 472 and EXPLORER are about equal and markedly superior to CHALLENGER. High seas induce pitch and roll, which cannot exceed about 7 degrees for safe drilling operations. The larger ships provide inherently better pitch and roll characteristics.

High Latitude Capability: All three ships would be capable of cold weather operations, with the larger ships better in this regard than the smaller. EXPLORER could be rated "Ice Class C," and an available sister ship to SEDCO 472, the 471, is classed "Ice Class B," which is a higher rating. CHALLENGER has no ice class. The class of the ship affects insurance costs and the willingness of a Master to operate in marginal areas, but there are no firm rules concerning the additional operational advantages of ice classing. None of the ships could actually drill in conditions involving other than very light ice. As a matter of policy, Sedco, Inc., would require an escort tug or ice breaker regardless of the ship's ice class.

Laboratory Facilities: Facilities on CHALLENGER are cramped and badly arranged. Only marginal improvements could be made. EXPLORER would offer truly outstanding facilities, equal to the best available on land in almost all respects. SEDCO 472 would offer a major improvement over CHALLENGER, but with the compromises generally associated with shipboard laboratories. The scanning electron microscope and microprobe planned for EXPLORER would not be possible on SEDCO 472, and there would be much less space for libraries, study carrels, and conference rooms. SEDCO 472 would, however, provide about twice the space now available on CHALLENGER, and in a superior arrangement.

III. Cost Summary

The daily operating and capital costs associated with each ship may be summarized as follows (1983 dollars):

	CHALLENGER	SEDCO 472	EXPLORER
Day Rate	$33,600	$32,200	$33,600
Fuel @ $320/ton	3,520	5,400	7,200
Fuel Type	Diesel	Diesel	Heavy Oil
Other Costs	12,200	12,200	11,800
	$49,320	$49,800	$52,600
Budget Estimate	$53 K/day	$53 K/day	$57 k/day
Capital Investment	$11 M	$10 M	$90 M

Within the limits of estimating accuracy, the operating costs of CHALLENGER and the SEDCO 472 are about the same, while EXPLORER is slightly more. The uncertainty is about 5 percent for either CHALLENGER or SEDCO 472, and perhaps 10 percent for EXPLORER.

For CHALLENGER and SEDCO 472 the figures are all based on recent operating experience. For EXPLORER the uncertainty is larger because there is no operating experience in the converted configuration, although the extrapolations we have made from past operating experience should be reasonably valid.

Capital Investment: The estimates for CHALLENGER and EXPLORER have been discussed elsewhere in detail. The estimates for SEDCO 472 are very preliminary, and may be subject to considerable error. The principal work required is as follows:

Modify Drill Rig for Scientific Coring Basis: Equipment quotes for EXPLORER	$ 1.0 M
New Larger Heave Compensator Basis: Direct vendor quote	1.5 M
Modify Station Keeping System for Deep Water Basis: Rough guess	.1 M
Modify Existing Hold for Lab Space Basis: Rough guess	1.0 M
Build Deckhouse for More Lab Space Basis: Rough guess	2.0 M

Laboratory Equipment Basis: EXPLORER lab equipment lists	2.0 M
Total	$ 7.6 M
Reserve	2.4 M
Budget Estimate	$10.0 M

IV. Impact on International Participation

The SEDCO 472 would allow the same size scientific party as has been planned for EXPLORER. The ship therefore has the size to accommodate additional partner countries. The cost advantages over EXPLORER should make possible a contribution level in the range of $2.5 M per year rather than the $3 M requested for EXPLORER. This would reduce the budget problems which new members have to cope with.

All present and prospective partners have indicated a strong desire for a new ship; none prefers to continue a program based on CHALLENGER. The information in this memo was presented and discussed at the JOIDES Planning Committee meeting on January 28, at which representatives of all four current partners plus Australia and New Zealand were present. All expressed enthusiasm for the concept of leasing a large drillship if terms similar to these can be obtained. Australia and New Zealand expressed a strong preference for such a ship over EXPLORER because of the immediate availability of a riser. The shorter hiatus in drilling possible with a leased drillship (less than a year vs. over 2 years with EXPLORER) is also attractive to the partners. In sum, international participation at the level of five to seven partners contributing $2.5 M each should be possible. I believe agreements could be negotiated on a long term basis with contributions beginning in FY 1985.

V. Conclusion

Technically the SEDCO 472 or a similar ship would be superior to CHALLENGER in every respect. Although inferior to EXPLORER in most respects, such a ship would have a major advantage over EXPLORER in the immediate availability of a riser.

Operating and capital costs for a leased drillship should be similar to those for CHALLENGER, and the capital investment required is much less than that required for EXPLORER.

International participation could be at levels approximating those possible with EXPLORER.

Under present market conditions the leased drillship option appears to present an opportunity to provide long term stability for the Advanced Ocean Drilling Program, based on a platform that is a major advance over CHALLENGER, at little or no increase in costs. Although attaining the most difficult of the COSOD objectives will eventually require a ship with capabilities approximating those planned for EXPLORER with the deep riser, the costs of such a ship are prohibitive at this time. I believe the community will support the choice of a large modern ship, to be leased through a competitive procurement, and that we should move forward with the necessary arrangements in the near future.

Allen M. Shinn, Jr.

January 31, 1983

SUMMARY OF BASIC DRILLSHIP OPTIONS*

OPTION 1: EXPLORER Drilling After Phase Out of CHALLENGER (Configuration "B")

	Actual FY 1982	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987-2005	Total 1984-2005	Average Cost per Drilling Year
CHALLENGER Ops	$ 18.1[1]	$ 18.0[2]	$ 2.2[5]	$ -0-	$ -0-	$ -0-		
EXPLORER Ops	-0-	-0-	-0-	-0-	10.4[12]	20.8		
Science	6.0	7.4[2]	9.3	9.5	9.6	13.5		
Design & Construction	5.5	6.0	29.6[6]	32.4	28.0	-0-		
TOTAL	$ 29.6	$ 31.4	$ 41.1	$ 41.9	$ 48.0	$ 34.3	$ 782.7	$ 40.1[16]
Less Foreign	- 8.4	- 8.3	- 4.6[7]	- 5.4[9]	- 12.0[13]	- 17.0[15]		
Less DARPA	- 1.2	- 0.1[4]	-0-	-0-	-0-	-0-		
NSF Appropriation	$ 20.0	$ 23.0	$ 36.5	$ 36.5	$ 36.0	$ 17.3	$ 437.7	$ 22.4[16]

OPTION 2: Refit and Continuation of CHALLENGER

	FY 1982	FY 1983	FY 1984	FY 1985	FY 1986-93	Total 1984-93	Average Cost per Drilling Year
CHALLENGER Ops	$ 18.1	$ 18.6[3]	$ 6.3	$ 20.8[10]	$ 20.8		
Science	6.0	8.5[3]	10.9	12.6	12.4		
Design & Construction	5.5	2.5	11.1	-0-	-0-		
TOTAL	$ 29.6	$ 29.6	$ 28.3	$ 33.4	$ 33.2	$ 327.3	$ 36.4[17]
Less Foreign	- 8.4	- 8.3	- 1.2[8]	- 8.0[11]	- 10.0[14]		
Less DARPA	- 1.2	- 0.1	-0-	-0-	-0-		
NSF	$ 20.0	$ 21.2	$ 27.1	$ 25.4	$ 23.2	$ 238.1	$ 26.5[17]

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*Figures in millions of 1983 dollars, except 1982.

SUMMARY OF BASIC DRILLSHIP OPTIONS

OPTION 3: EXPLORER Drilling After Phase Out of CHALLENGER (Configuration "C")

	Actual FY 1982	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987-2005	Total 1984-2005	Average Cost per Drilling Year
CHALLENGER Ops	$ 18.1	$ 18.0	$ 2.2	$ -0-	$ -0-	$ -0-		
EXPLORER Ops	-0-	-0-	-0-	-0-	11.1	22.2		
Science	6.0	7.4	9.3	9.5	9.6	13.5		
Design & Construction	5.5	6.0	24.1	25.8	25.1	-0-		
TOTAL	$ 29.6	$ 31.4	$ 35.6	$ 35.3	$ 45.8	$ 35.7	$ 795.0	$ 40.8[16]
Less Foreign	- 8.4	- 8.3	- 4.6	- 5.4	- 12.0	- 17.0		
Less DARPA	- 1.2	- 0.1	-0-	-0-	-0-	-0-		
NSF Appropriation	$ 20.0	$ 23.0	$ 31.0	$ 29.9	$ 33.8	$ 18.7	$ 450.0	$ 23.1[16]

OPTION 4: Use of Existing Commercial Ship beginning 1985 *

	FY 1982	FY 1983	FY 1984	FY 1985	FY 1986-93	Total 1984-93	Average Cost per Drilling Year
CHALLENGER Ops	$ 18.1	$ 18.6	$ 2.2	$ -0-	$ -0-		
New Ship Ops	-0-	-0-	2.9	20.8	20.8		
Science	6.0	8.5	10.9	13.5	13.5		
Design & Construction	5.5	2.5	10.0	-0-	-0-		
TOTAL	$ 29.6	$ 29.6	$ 26.0	$ 34.3	$ 34.3	$ 334.7	$ 37.2[18]
Less Foreign	- 8.4	- 8.3	- 1.2	- 12.5	- 12.5		
Less DARPA	- 1.2	- 0.1	-0-	-0-	-0-		
NSF	$ 20.0	$ 21.2	$ 24.8	$ 21.8	$ 21.8	$ 221.0	$ 24.6[18]

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*Costs based on unsolicited proposal.

OPTION 1: EXPLORER DRILLING AFTER PHASE OUT OF CHALLENGER
(Configuration "B")

	Actual FY 1982	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987-2005
CHALLENGER Ops						
Drilling Contract	$12,764	$13,741	$ 1,167	$ -0-	$ -0-	$ -0-
SIO Hdqtrs	578	585	383			
Ops (Inc Logging)	4,355	3,276	331			
Logistics Office	426	437	352			
CHALLENGER Subtotal	$18,123	$18,039	$ 2,233	-0-	-0-	-0-
EXPLORER Ops	-0-	-0-	-0-	-0-	$10,400	$20,800
Science						
SOC Hdqtrs	578	585	575	500	600	600
Sci Ops	611	645	550	350	350	800
Sci Services	1,248	1,402	1,400	1,200	1,000	1,500
Team Support	125	126	20	-0-	600	1,225
Tech Support	1,124	1,154	300	100	1,000	1,990
Engineering	507	574	1,000	1,000	1,000	800
JOIDES	556	784	650	650	650	650
Site Surveys	834	1,661	3,700	4,625	3,700	3,700
Syntheses	-0-	-0-	600	600	600	1,200
Downhole Exp.	-0-	-0-	-0-	-0-	250	500
Publication	450	500	500	500	-0-	500
Science Subtotal	$ 6,033	$ 7,431	$9,295	$ 9,525	$ 9,550	$13,465
Design & Construction	$ 5,500	$ 6,000	$29,600	$32,400	$28,000	-0-
TOTAL	$29,656	$31,470	$41,100	$41,900	$48,000	$34,300
Less Foreign	- 8,456	- 8,370	- 4,600	- 5,400	-12,000	-17,000
Less DARPA	- 1,200	- 100	-0-	-0-	-0-	-0-
NSF Appropriation	$20,000	$23,000	$36,500	$36,500	$36,000	$17,300

OPTION 2: REFIT AND CONTINUATION OF CHALLENGER

	FY 1982	FY 1983	FY 1984	FY 1985	FY 1986-93
CHALLENGER Ops					
Drilling Contract	$12,764	$13,741	$ 3,925	$15,750	$15,750
SIO Hdqtrs	578	585	575	600	600
Ops (Inc Logging)	4,355	3,876	1,600	4,000	4,000
Logistics Office	426	437	200	450	450
CHALLENGER Subtotal	$18,123	$18,639	$ 6,300	$20,800	$20,800
Science					
SOC Hdqtrs	578	585	575	600	600
Sci Ops	611	645	550	650	650
Sci Services	1,248	1,402	1,400	1,400	1,400
Team Support	125	226	-0-	900	900
Tech Support	1,124	1,154	300	1,200	1,200
Engireering	507	774	1,500	1,000	800
JOIDES	556	784	650	650	650
Site Surveys	834	2,461	4,625	4,625	4,625
Syntheses	-0-	-0-	800	800	600
Downhole Exp.	-0-	-0-	-0-	250	500
Publication	450	500	500	500	500
Science Subtotal	$ 6,033	$ 8,531	$10,900	$12,575	$12,425
Design & Construction	$ 5,500	$ 2,500	$11,100	$ -0-	$ -0-
TOTAL	$29,656	$29,670	$28,300	$33,375	$33,225
Less Foreign	- 8,456	- 8,370	- 1,200	- 8,000	-10,000
Less DARPA	- 1,200	- 100	-0-	-0-	-0-
NSF Appropriation	$20,000	$21,200	$27,100	$25,375	$23,225

OPTION 4: USE OF EXISTING COMMERCIAL SHIP BEGINNING 1985

	Actual FY 1982	FY 1983	FY 1984	FY 1985	FY 1986-93
CHALLENGER Ops					
Drilling Contract	$12,764	$13,741	$ 1,167	$ -0-	$ -0-
SIO Hdqtrs	578	585	383		
Ops (Inc Logging)	4,355	3,876	331		
Logistics Office	426	437	352		
CHALLENGER Subtotal	$18,123	$18,639	$ 2,233	-0-	-0-
New Ship Ops	-0-	-0-	$ 2,900	$20,800	$20,800
Science					
SOC Hdqtrs	578	585	575	600	600
Sci Ops	611	645	550	800	800
Sci Services	1,248	1,402	1,400	1,500	1,500
Team Support	125	226	-0-	1,225	1,225
Tech Support	1,124	1,154	300	1,990	1,990
Engineering	507	774	1,500	800	800
JOIDES	556	784	650	650	650
Site Surveys	834	2,461	4,625	3,700	3,700
Syntheses	-0-	-0-	800	1,200	1,200
Downhole Exp.	-0-	-0-	-0-	500	500
Publication	450	500	500	500	500
Science Subtotal	$ 6,033	$ 8,531	$10,900	$13,465	$13,465
Design & Construction	$ 5,500	$ 2,500	$10,000	$ -0-	$ -0-
TOTAL	$29,656	$29,670	$26,033	$34,265	$34,265
Less Foreign	- 8,456	- 8,370	- 1,200	-12,500	-12,500
Less DARPA	- 1,200	- 100	-0-	-0-	-0-
NSF Appropriation	$20,000	$21,200	$24,833	$21,765	$21,765

1/ In 1982 CHALLENGER ops is high and science is low because of the purchase of a new drill string.
2/ Assumes CHALLENGER phases out at end of FY 1983.
3/ Assumes CHALLENGER operates in FY 1983 in steady state.
4/ DARPA wishes to add a 30 day program to current CHALLENGER schedule. Additional costs will be directly offset by additional DARPA reimbursement of approximately $2.0 million to be received in FY 1984.
5/ Operations through October 21, 1983 plus demobilization.
6/ Conversion cost estimate is $80.3M. Planning is at $90M to allow for uncertainties.
7/ Assumes $1.2M phase out (current agreements) plus $1M/ea from France, FRG, and UK, and $.2M/ea from Canada and one other new member.
8/ Phase out payments under current agreements.
9/ Assumes $1M/ea from France, FRG, UK, plus $2M from Japan, plus $.2M/ea from Canada and one other new member.
10/ Operating budget from either ship is [($50K/day X 365) + $575K SIO O/H] X 1.1 to adjust to 1983 dollars.
11/ Four current partners @ $2M/ea.
12/ Assumes 6 months operations.
13/ Assumes 1/2 yr @ $1M/yr/partner plus 1/2 yr @ $3M/yr/partner.
14/ Five partners @ $2M/ea.
15/ Assumes 5-6 full partners @ $3M/ea.
16/ Assumes 19.5 year productive life for EXPLORER.
17/ Assumes 9 year productive life for CHALLENGER after refit.
18/ Assumes 9 year productive life for an existing commercial ship.

TABLE I.

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000')	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
A. INTEGRATION OF CONTINENTAL AND OCEANIC STUDIES			
I. Continent-Ocean transects (rifting, drifting and subsidence history)	Possible with carefully selected shallow holes exploiting structural and stratigraphic variability. Experience shows heave compensation system unsatisfactory	Same as for CHALLENGER but deeper penetration (2-3Km) if safety can be assured. Heave compensation system satisfactory	Riser increases ability to pump mud, stabilize hole and circulate fluids. Penetration of 5 km feasible. The presence of a riser with BOP also insures safety on margin areas. Heave compensation system satisfactory
II. Pre-cretaceous sedimentary history - transitional ocean crust			
III. Biostratigraphic correlations			Station keeping ability as good as EXPLORER
IV. Conjugate margins; correlations of deep seismic reflections, Age and nature of basement			
V. Oldest oceanic rocks of the Atlantic			
VI. Research oriented resource evaluation (clathrates, mineralization, ore genesis, hydrocarbon maturation)			
VII. Dating of continent - Ocean unconformities			

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000')	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
B. OCEAN CRUST			
I. Deep Crustal penetration into layers II and III to understand origin of oceanic crust. a) Understand nature and composition of layer II-III transition and layer III. b) Origin of magnetic signature, paleomagnetic reversals and refinement of sea floor spreading processes; origin of magnetic quiet zones. c) Hydrothermal circulation within Layer II and III; convection and sea-water interchange and alteration processes. d) Metamorphic structure as function of age. e) Test Ophiolite model.	Total depth of penetration needed is 1.5-3.0 km. The deepest penetration thus far into oceanic crust is 1,080m (Hole 504B). CHALLENGER's capability to drill deeply into the crust is limited by: o Weather sensitivity Inability to stay on station and keep drilling in heavy weather; Inability to handle reentry cones and casing strings at deep depths except in calm weather. o Inability to carry substantial casing (2500' vs 57,000' on EXPLORER). o Inability to carry large supplies of mud and cement (1000 sacks storage vs. 28,000 sack capacity on EXPLORER). o Heave compensation system not satisfactory.	EXPLORER's size provides better weather tolerance and essentially unlimited storage of mud, cement, and casing. o Weather tolerance allows fewer interruptions to drilling and better ability to run casing. o Casing stabilizes the hole prevents caving in problem areas. o Mud speeds penetration and helps keep hole clear. o Amount of increased penetration can't be accurately predicted. Perhaps a factor of two. o Heave compensation satisfactory	Riser increases drill penetration potential to depths of about 5 km, in water depths of 6-8000'. Thus scientific objectives are easily within capabilities. Increased pumping ability and closed mud circulation improves drilling conditions. Heave compensation satisfactory

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000')	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
II. Drilling on young oceanic crust. a) What is character of new oceanic crust? b) Nature of thermal and mass exchange in high temperature ridge crest convection systems. c) Penetration into, or close to, ridge crest magma chambers. d) Origin and history of polymetallic sulphides.	Highly brecciated rocks of the Ridge Crest most difficult for drilling - o Need availability of mud, cement and casing to secure problematic zones. o Need new technology to drill into sediment free surface. o Heave compensation not satisfactory	Capability to carry large amounts of mud, cement and casing critical for penetration. Need new technology to drill into sediment free surface: large vessel facilitates use of large stabilizing devices.	Deeper penetration into ocean crust with riser is feasible, if suitable sites in water depths less than 8000' (2250m) are available
III. Source Region Characteristics a) Mantle chemistry and heterogeneity. b) Fast vs slow spreading ridges.	Require shallow (100-300m) penetration into volcanic carapace - CHALLENGER satisfactory.	EXPLORER Satisfactory	Other platforms satisfactory

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000')	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
C. CONTINENTAL MARGINS - PASSIVE			
I. Deep penetration of sedimentary wedge to recover record of continental fragmentation. a) Establish sedimentary, thermal and structural history of basins developing along continental margins. b) Calibrate regional significance of multi-channel seismic profiles and reflectors. c) Regional calibration of transgressive and regressive cyles (tectonics vs eustatic) d) Large scale submarine erosional cycles.	Deep penetration (greater than 2 km) required. (see B.I.). Possible solution through integration of shallow holes using carefully selected sites exploiting topographic and structural opportunities.	Greater penetration (see B.I.). Ultimately, the very deep penetration and well control provided by the riser planned for OMD will be required.	Scientific objectives are more easily reached with riser. Increased circulation of mud enhances hole stability. Riser also offers the safety required to prevent blowouts or oil spills. Penetration of 5 km is possible.
II. Identification and intepretation of deep seismic reflectors. a) Understand origin and lithologic character of deep seismic reflectors. b) Deposition history and age of seaward dipping and landward dipping reflectors in selected passive and active margins.	Limited penetration (see B.I.). Required penetration is greater than 1.8 km. Maximum CHALLENGER penetration has been about 1.7 km in sediments. Shallow holes (less than 500m) possible.	Greater penetration (see B.I.).	same as above

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000')	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
III. Identification of Bottom Simulation Reflector (BSR) clathrate distribution, chemistry and origin			
D. CONTINENTAL MARGINS - ACTIVE			
I. Structure and Dynamics of Subduction Zones. a) Origin and age of sediments and rocks in accretionary wedge. b) Structural, stratigraphic relationships in accretionary wedge c) Study changing physical & mechanical properties of sediments during lithification as they relate to structural evolution (lateral and vertical motion). d) Examine tensional, compressional and rotational histories of subduction zones.	Penetration of 1-3 km in water depths in excess of 20,000 ft in many trenches o Reentry cones and casing cannot be run in deep water except under ideal weather conditions. o Poor heave compensation reduces drilling efficiency. o Problems with local overpressured zones cause serious caving in of hole; limited capabilities to control problem. o Mud and casing limits as in B.I.	o Ability to handle 33,000' of drill string. o Better inherent heave characteristics to run re-entry cones and casing. o Effective heave compensation improves drilling efficiency. o Essentially unlimited supplies of mud and casing to bypass overpressured zones.	Riser allows for much deeper penetration (up to 5 km possible). Better circulation system, added safety if hydrocarbons traps are pierced.
II. Tectonics of non accretionary vs accretionary trenches			

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000)	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
III. Age and origin of accreted material and underthrust sediments			
E. HISTORY OF OCEAN BASINS			
I. Recovering and dating the oldest oceanic sediments and rocks. a) Test plate tectonic model. b) Test oceanic subsidence heat flow models. c) Interpret geologic history of ocean basins. d) Study of remnants of Paleozoic oceans. e) Biostratigraphic correlation of Mesozoic strata.	Oldest sediments and rocks should be found in deep ocean basins and trenches, in water depths of 20,000' or deeper. CHALLENGER's ability to work in very deep water is subject to drill string limitations: o CHALLENGER can rack and handle no more than 23,000' of drill string. o In even moderate weather, CHALLENGER's small size leads to heaving which imposes an additional dynamic load on the drill pipe. This causes limits on ability to run reentry cones or casing in deep water, when the heave compensator cannot be used. o CHALLENGER's heave compensator reaches an absolute limit at 23,000', and is increasingly ineffective at depths below about 18,000'.	o EXPLORER will rack 33,000' of pipe. o Because of size, heave is inherently less than CHALLENGER's o Heave compensator will have a design limit of 1,000,000 lbs, vs CHALLENGER design limit of 600,000 lbs and actual limit of 460,000 lbs. This will allow heave compensation at all water depths. o Aluminum pipe or small diameter pipe at the bottom can be used to extend pipe below absolute limit of 29,000' for SY-135 5" steel pipe.	Similar to EXPLORER Capabilities. Riser cannot be used in depths over 8000' (2250m)

Basic Scientific Question	CHALLENGER Capability (23,000' drill string capability)	EXPLORER Capability (33,000')	Other Platforms (riser capability 6000'-8000' with 30,000' drill string)
F. PALEOENVIRONMENTAL STUDIES			
I. High Latitude Drilling: a) Key to Paleo-oceanic circulation b) Initiation of present day thermohaline circulation c) Timing and extent of glacial periods d) Relationship between tectonics and Paleo-ocean circulation e) Correlation of sea level transgressions and regressions with tectonics and glacial periods f) High organic productivity yields maximum resolution (paleomagnetics, biostratigraphy, paleoenvironment).	High latitude drilling requires weather windows, which may or may not be long enough and calm enough to allow CHALLENGER to succeed. CHALLENGER can drill normally in weather that causes rolls of no more than 7°. Past legs have been only marginally successful.	Size reduces vessel motion in any given sea state. EXPLORER can roll up to 7° without affecting drilling (this limit is related to working safely on the drill floor). For EXPLORER this roll limit will not be exceeded in conditions up to 15' significant seas, 45 knots of wind, and 2.5 knots of current. CHALLENGER's limits are less than these, but not precisely known. The chance of success for EXPLORER is therefore significantly greater than for CHALLENGER, but the actual difference depends on the weather when the ship is on station.	Ability to drill on margins with riser allows for the completion of paleoenvironment transects and correlation with continental boreholes and geologic sections Station keeping ability as good as EXPLORER

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

PROCUREMENT, LOGISTICS,
AND READINESS DIVISION

B-210495

March 4, 1983

The Honorable Don Fuqua
Chairman, Committee on Science
and Technology
House of Representatives

Dear Mr. Chairman:

Subject: National Science Foundation's Expenditures for Planning the Overhaul and Conversion of the U.S. Government Ship Glomar Explorer for Deep Ocean Scientific Drilling Purposes (GAO/PLRD-83-47)

On November 1, 1982, representatives of your office asked us to determine how much money has been spent in planning the conversion of the Glomar Explorer from a mining ship to a mobile scientific deep ocean drilling platform. We were asked also to give our opinion of the management controls used by the National Science Foundation (NSF) to assure the reasonableness of expenditures. Based on further discussions with your representatives, we were asked to focus on the contract with Lockheed Missiles and Space Company, Inc.

We made our review in accordance with generally accepted government audit standards. At NSF Headquarters, we interviewed officials and reviewed contract files, interagency agreement records, and scientific and technological reports on the ocean drilling program. We did not audit the costs charged to the project, but we did identify the management controls and techniques used by NSF to assure that the project was reasonably conducted. Our work indicates that NSF expenditures have been reasonably controlled.

Since 1975 NSF has awarded $16,400,394 in appropriated funds and $5,120,333 in nonappropriated funds to various scientific and contracting organizations for determining the merits of deep ocean scientific drilling and the means to achieve such drilling (see enc. I). Of the total $21,520,727, all but $107,000 was used for scientific and engineering studies related to the ship Explorer as the primary candidate for a mobile drilling platform.

(943557)

The Explorer conversion project evolved from a contractual study done in 1975 by the Ocean Resources Engineering Company (ORE) which was tasked by NSF to determine the type of platform and equipment required to achieve deep ocean drilling for scientific purposes. ORE noted that a properly equipped large surface ship was the best option. Using ORE's results, a second contract was let with Global Marine Development, Inc., to determine whether the Explorer was a viable candidate for the platform. Global concluded it was.

NSF competitively contracted with Donhaiser Marine, Inc., to evaluate both the ORE and the Global reports for reasonableness. Donhaiser concluded each report was accurate and reasonable.

With these results as a basis, NSF competitively let a contract with Santa Fe Engineering Services Company to develop a conceptual baseline design of how the Explorer could be overhauled and converted to perform deep ocean scientific drilling given the recommended equipment described in the earlier three reports. The Santa Fe contract produced the required concept from which a contract was competed for developing first a preliminary design--a reasonable representation of the rough configuration of the converted Explorer--followed by bid-quality blueprints (known as a contract design) of the method to overhaul and convert the Explorer. Santa Fe's concept design required 2 years to develop at a cost of $4,384,638 in appropriated funds plus $846,730 in nonappropriated funds.

Following Santa Fe's work, NSF solicited bids for the Systems Integration Contract for the Ocean Margin Drilling Program, subsequently renamed the Advanced Ocean Drilling program. The contract was for (1) the production of a preliminary design and a contract design, (2) the management of the Explorer's conversion and fabrication, (3) the final acceptance testing and initial operations of the Explorer, and (4) the expected operation and maintenance of the converted Explorer.

In November 1981 Lockheed successfully competed for the contract. The contract has been awarded $6,983,133, which represents about 32.4 percent of the total Explorer-related funding. Lockheed's contract was initiated with an incremental award of $1.2 million, which was increased twice during fiscal year 1982: the first was $2,795,000 and the second was $1,188,133. Total fiscal year 1982 funding awarded to Lockheed came to $5,183,133, an amount just short of the $5.2 million authorized by the National Science Board--NSF's governing body.

Lockheed's planned funding needs for fiscal year 1983 totaled $4,780,971, which includes a fixed fee of $391,096. However, the initial fiscal year 1983 award was for $1.8 million to cover Lockheed performance through January 1983, subsequently extended through March 11, 1983. Expenditures during this period cannot be precisely determined, but may be less than awarded because NSF, for the convenience of the Government, partially terminated the contract effective January 3, 1983, allowing only some tasks to receive wrap-up funding. Complete termination is scheduled for March 11, 1983.

As the systems integration contractor, Lockheed was to provide engineering expertise and services necessary to the design, conversion and fabrication, testing, operation, and support of the drilling vessel and the installed drilling system for the Advanced Ocean Drilling Program. Contract responsibilities were to be met in four phases:

--Phase I-Design. The phase was originally intended as a 1-year activity. Due to funding changes this phase has been divided into Phase IA-Preliminary Design to be achieved in fiscal year 1982 and Phase IB-Contract Design to be achieved during fiscal year 1983.

Preliminary design allows NSF (and its advisory organizations) detailed configurations of the drilling vessel's requirements to meet identified objectives. From these configuration plans, NSF can evaluate the merits of continuing with the Advanced Ocean Drilling Program and its essential equipment--the converted and appropriately equipped Explorer.

Preliminary design has been virtually completed and NSF has partially funded contract design. To be completed in fiscal year 1983, the contract design requires Lockheed to have detailed plans ready so that upon NSF approval competitive shipyard selection can be achieved for the conversion and fabrication of Explorer and its drilling system. The contract's termination affects the completion of this and the remaining three phases.

--Phase II-Conversion and Fabrication. This phase was planned for the period October 1983 to June 1985. As the systems integration contractor, Lockheed was to manage and implement all efforts required to convert the ship and fabricate the drilling systems.

- --Phase III-Final Acceptance Testing and Initial Operations. This phase was expected to begin in July 1985 and end in June 1986. The contractor was to oversee problems or deficiencies.

- --Phase IV-Operations and Maintenance. This phase was to begin in July 1986. It was to require the systems integration contractor to support ship operations which were to be conducted in close liaison with the science contractor (presently the Joint Oceanographic Institutions, Inc.).

Using science and engineering consulting contracts and interagency agreements, NSF has assured itself that the continued need for deep ocean drilling exists and that the Explorer is the most viable option for achieving the scientific objectives. Further, NSF has repeatedly verified the costs of its contract awards as well as the conversion cost estimates provided by contractors charged with developing such estimates.

NSF surveillance of Lockheed's actual and planned expenditures and cost projections for the contract phases demonstrates the diligence NSF has applied to contracts during the Explorer program. The Lockheed proposal and the proposals of competitors were critically reviewed by a large panel of external scientific, engineering, and management experts as well as experts from within NSF. Contract invoices and progress reports have been reviewed for reasonableness and compliance by NSF's staff within the Office of Scientific Ocean Drilling. Contract deliverables--interim or final products--receive both internal review and, as necessary, expert external review through pre-awarded consulting contracts and interagency agreements. NSF, from time to time, has asked the scientific community, engineering professionals, and management consultants to evaluate various components and deliverables of Lockheed's contract. NSF appears to have done a reasonable job of protecting its investments in Explorer-related activities.

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As your office directed, we did not obtain official agency comments on the content of this report. However, throughout the course of our work, agency officials were continuously informed of our observations.

We are sending copies of this report to the Directors of the National Science Foundation, the Office of Management and Budget, and the Office of Science and Technology Policy, and to the Chairmen of appropriate congressional committees. Copies will also be made available to other interested parties upon request.

Sincerely yours,

Donald J. Horan

Donald J. Horan
Director

Enclosure

Mr. WALGREN. Will your $9.8 million cover your anticipated expenses in the next year, even going forward with a different vehicle?

Dr. KNAPP. Yes.

Mr. WALGREN. So that is all you anticipate asking for in this next fiscal year, regardless of how that choice comes out?

Dr. KNAPP. If the ocean sciences programs and the ocean drilling programs are lumped together, we may ask for some change in the division of funds between ocean sciences and ocean drilling, but that would be the extent of our request.

Mr. WALGREN. Now, there were some foreign contributions to this effort that apparently are not continuing, at least at the moment. Can you tell us what to expect in that area?

Dr. KNAPP. Yes, sir.

If we go forward with the leased ship, we will go to our partners and solicit fiscal year 1984 contributions to defray planning costs. The amount would be much less than $1 million, perhaps $200,000 to $500,000 per partner. The amount would depend upon our detailed plans.

I understand that in ocean drilling with the *Explorer* or with a leased ship we can expect full participation of the international partners again—perhaps an expanded group of partners—when the drilling program comes back into operation.

Mr. WALGREN. Thank you, Dr. Knapp.

Mr. Bateman.

Mr. BATEMAN. I have no questions, Mr. Chairman.

Mr. WALGREN. If I could touch on a couple of other subjects, we have in the past been concerned about the infrared telescope in Hawaii, which is presently supported by NASA. There had been suggestions of coordination of that support with NSF.

Where does that stand in your plans?

Dr. KNAPP. When the fiscal year 1984 budget was prepared, the issue was raised between the Foundation, NASA, and the OMB. The OMB decided to leave the infrared telescope in the 1984 budget for NASA.

As recently as February 25, the discussions between NASA and NSF centered on NASA funding that facility in fiscal year 1984.

Dr. SALPETER. Mr. Chairman, if I may express here the view of the infrared astronomers: They would prefer that the project remain with NASA because about 80 percent of infrared astronomy is done not from the ground but from space. Such research is supported by NASA. The same astronomers spend maybe 20 percent of their time looking from ground-based telescopes. Consenquently, there is some slight advantage if the ground-based facilities supporting the space work are also managed by NASA.

Mr. WALGREN. The very long baseline array radio telescope, if that is the way it is known, where are we in that program, and when do you see construction of facilities, and what kinds of facilities are involved in that sort of program?

Dr. KNAPP. The funds for fiscal year 1984 are to carry out a design study of the facility. Construction of the facility would be started with fiscal year 1985 funds.

The VLBA, as it is called, is a series of radio telescope dishes placed across the United States into Alaska, perhaps in Hawaii. It involves the synchronized operation of these dishes to make precise images of radio sources.

Perhaps Dr. Salpeter would comment on some technical details.

Dr. SALPETER. There is an interesting contrast between two rather major projects, both of which Dr. Field will discuss later for the panel.

His panel had advocated two major projects in ground-based astronomy, the very large baseline array of radiotelescopes and a new technology optical telescope. On purely scientific grounds, the panel had not made a value judgment. Both projects are important, but they work in different areas. However, in the matter of timing, and for reasons of purely technological innovation, there is a great difference. Essentially, the VLBA is ready to go now. For the final design one needs to know where to put the nuts and bolts, but no major breakthrough is required in the technology. But for the new technology telescope—the real drama at the moment and at least during the next couple of years—it is really a matter of which technology is the best.

Do you make one single, very thin mirror? Do you make mirrors that are almost like an egg crate to give stability? Is it dozens of separate mirrors? Is it mirrors that are hinged together?

So there is a great difference on the time scale. I hope the VLBA will be long finished before construction starts on the next big optical telescope.

Mr. WALGREN. Turning to the atmospheric sciences, do we have an unmet computer need in atmospheric sciences at this point? I am particularly thinking of the National Center for Atmospheric Research.

Dr. KNAPP. I believe we do. As in any of the computational sciences, as one learns how to make computations with the state-of-the-art computing equipment, the possibilities of doing a better and more complete job always come up. The possibilities of using the new generation of supercomputers, the CRAY II computers, in the future at NCAR and Colorado for atmospheric and climate modeling look very exciting. To do so would require the addition of a larger computer at that center. It is in the future plans for funding from the Congress.

Mr. WALGREN. But it is not presently reflected in this year's budget request.

Dr. KNAPP. That is right. It is not presently being requested.

Mr. WALGREN. Has the NSF done an overall computer survey of its needs in various programs, and are there ways that, through transmission of data, access can be given to more sophisticated computer services that might be available in another place or another program?

Dr. KNAPP. At the present time, the computer at NCAR is available by remote line to investigators in other universities who are doing calculations with the models resident in the computer at NCAR. In that sense, for this one scientific discipline within NSF's budget, we do provide access to the supercomputer at NCAR for investigators in the atmospheric sciences.

The Foundation is just now starting to survey the mathematical and computer sciences for supercomputing requirements. The survey was spurred partly by Dr. Wilson's request. But it was also spurred by the requests of many others in many disciplines who believe the supercomputer is necessary to their work and who need access in the universities so that graduate students can also be trained in the use of these large facilities.

Dr. **Salpeter**. NCAR has been farsighted in how it defines atmospheric sciences where the use of the super computer is concerned. People in allied areas where the methodology is similar to that of the atmospheric sciences also, have been able on occasion to use the computer there.

One of my graduate students is interested in huge galaxies and the intergalactic gas. The subject is different from the terrestrial atmosphere, but the methodology of the hydrodynamic calculations is similar. He has been able to get free time on the computer, and there is some back-and-forth in methodology between different sciences. I feel such exchange is always useful if it can be achieved.

Mr. **Walgren**. But NSF has not had a task force, really, and perhaps should not, looking at what the potentials for computers are and the needs throughout and how they can best be met.

Dr. **Knapp**. NSF should have such a task force. NSF also should try to integrate the requirements of many of the agencies of Government in order to understand what science as a whole needs in supercomputing capability.

The DOD, the DOE, the NSF, NASA, the Institutes of Health all have interests in some areas which would require supercomputers. It seems unreasonable to try to do all of these separately. Over the next few years, we will see developed networks between these types of computers which will allow access between different scientific disciplines and between different investigators funded by different agencies. It is a difficult and time-consuming task, and we are just now trying to understand how to get started on those investigations.

Mr. **Walgren**. Turning to the Earth sciences, I understand the National Academy of Sciences has a report on priorities in Earth science research. Has that report been issued, and if so, what has been our response to it through NSF?

Dr. **Knapp**. I am not familiar with that report. I will ask my staff to reply for the record.

Mr. **Walgren**. All right, fine.

[Material to be supplied follows:]

PRIORITIES IN EARTH SCIENCE RESEARCH

A report entitled Opportunities for Research in the Geological Sciences is now in preparation by a committee of the Geological Sciences Board of the National Academy of Sciences. This report, expected to be published on July 1, 1983, is based on the results of a broad survey of the field including 24 professional societies, 140 geological science departments in universities, and a variety of government agencies and other organizations engaged in geological research.

Mr. **Walgren**. Then, in the area of oceanography, we are not increasing that area to the degree that we are some others—ocean sciences. They oceanographers are receiving an increase but something in the range of 10 percent. Oceanography is one area that is obviously related to the climate research, and yet there is no mention of that factor in the ocean sciences budget.

Are you satisfied that we are taking proper account of the relationship of climate to the ocean sciences effort in particular?

Dr. **Knapp**. Yes; I believe we are. Let me explain the the apparently low increase in the ocean sciences. If the total funds for oceanographic research and ocean drilling are summed, the increase for ocean drilling and ocean sciences is 17 or 18 percent. The intent was to include ocean drilling within the ocean sciences and provide an increase about level with the increase received by the rest of the Foundation.

Mr. **Walgren**. Well, thank you very much, Dr. Knapp. There is an infinite area there to cover, and we will be interested in developing bits and pieces of those areas with you because the committee is genuinely concerned with those areas. I know particular members have followed some of those programs more closely than others and more closely than I have. So we look forward to getting your additional views, in writing.

We appreciate your coming today very much to talk about this area.

Dr. **Knapp**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you.

Next is the panel on oceanography and ocean drilling, with Dr. Charles Drake, chairman of the Ad Hoc Advisory Group on Crustal Studies; Dr. William Nierenberg, the director of the Scripps Institute of Oceanography; and Dr. Derek Spencer, associate director for research at Woods Hole Oceanographic Institution.

Your written statements will be made part of the record. Please summarize in some way, if you can. We are running late, and I apologize for that. Please proceed, and we will be most interested in the light you have to shed on this area.

We will start with Dr. Drake.

STATEMENT OF DR. CHARLES L. DRAKE, CHAIRMAN, AD HOC ADVISORY GROUP ON CRUSTAL STUDIES, NATIONAL SCIENCE FOUNDATION

Dr. **Drake**. Thank you, Mr. Chairman. I will abbreviate the comments that you have in written form.

I was chairman of an ad hoc committee which was asked by the National Science Foundation to review plans for ocean scientific drilling in the context of crustal studies. Now, putting ocean drilling in the context of crustal studies is logical because the crust of the Earth extends beneath the waters of the ocean, as well as beneath the surface of the land. Much of the land surface is created by processes that take place in the ocean.

In many ways, ocean drilling has more in common with geology on land than it does with other aspects of oceanography. This could also be said of marine geology and geophysics, but it makes some sense to discuss these topics in terms of oceanography because common facilities are required to carry out the investigation.

Before I discuss the options for ocean drilling specifically, let me say just a few words about crustal studies in general. Geology was a descriptive science for many years because no one knew what was there. Until you found out what was there, it was difficult to devise theories that would adequately explain how it got there or what might happen in the future. Over the years, we have explored the surfaces of the continents fairly extensively, and we have identified the major features and the gross properties of the sea floor. We have not been as successful in exploring the third dimension, that of depth, until recent years because we did not have the tools for detailed remote sensing of the subsurface, nor did we have the funds to apply the drill.

In the last decade, geology has focused more on processes, and this focus was given great impetus by the development of the plate tectonics model, which views the Earth's outer shell as broken into a large number of very small plates moving relative to each other. The edges of these plates are marked by earthquakes and the movements may be convergent, making island arcs and mountain systems, such as in Alaska; divergent, making ocean ridges like those off the Pacific Northwest; or the plates may slide along each other as in the San Andreas Fault system of California.

We are interested in past processes. We explore to see what they have left for us, and we try to figure out what they were. We are interested in present processes because these not only give us some clues that we can apply to the past, but they give us some hope of looking into the future for predicting. Prediction extends beyond the anticipation of future events. It also includes the attempt to predict world and national energy, mineral, and environmental resources.

If we are to respond to the intellectual challenge of finding out how the Earth works and to the societal need for better information about the Earth, we will have to learn a great deal about the Earth processes and their rates. We will need to examine the Earth in depth. We will have to probe the deep interior, which is the source of the heat which drives the processes. We will need to understand, as Captain Cousteau said, the interfaces, the transitions from one to the other.

The drill is just the tool, but it is a tool that can make important contributions to this understanding. It would be a very expensive tool to use for primary exploration, but it may well be the only tool that can be used for confirmation or rejection of models developed from geological, geophysical, or geochemical investigation. It can clarify many uncertainties, and it can reveal many surprises. Scientific ocean drilling provided the confirmation for the model of formation of the ocean crust from sea floor spreading, a model that was suggested by geophysical measurements.

Drilling demonstrated the presence of salt domes and hydrocarbons in the deepest part of the Gulf of Mexico. Recent ultradeep drilling on land in the Soviet Union, on the Kola Peninsula, has reached 11.5 kilometers and is planned for 15 kilometers. The temperature gradients are not at all what one would expect from shallow, near-surface measurements. Geophysical discontinuities determined from the surface do not appear to be reflected in the geology at depths. Liquids are circulating through the rocks through its entire depth, although common wisdom would suggest that the pores should be closed below 10 kilometers. Sulphide mineralization was found at depths of over 9.5 kilometers.

The drill has been a particularly valuable tool in the oceans because of their youth and their exposure to fewer thermal or deformational events. This meant that the data from a limited number of holes could provide answers to questions over a broad area. As the program has matured, more detailed questions can be asked and answered.

Ocean drilling has been a scientific program from the beginning, but there has been a constant effort to adapt new tools to provide new and better information. We can now reenter holes to probe more deeply, and we can instrument holes for in situ measurements. The hydraulic piston corer, which was introduced in 1979, and the recently introduced extending-core barrel allow us to recover undisturbed samples so that the history of the ocean basins or the circulation of ocean waters and of the climate above the ocean surface can better be determined.

These undisturbed samples have taken on a new significance in the last few years, following the suggestion that large extraterrestrial bodies have impacted the Earth, causing massive extinctions of life forms and replacement of these by new life forms; that evolution of life may be punctuated rather than gradual; that we may be dealing with the survival of the luckiest rather than the survival of the fittest.

A continuous marine sequence can obviously be found only in the oceans. Sedimentation rates are slow, on the order of a few centimeters per thousand years, and the new tools provide the time resolution necessary to identify events. The previously drilled low-time-resolution holes tell us where to go to answer specific questions.

Now let me turn to the platform for scientific ocean drilling. The ad hoc committee I chaired was looking at scientific ocean drilling in the context of crustal studies, and the committee consisted of a broad mix of geologists, geophysicists, and geochemists, and oceanographers from academia and industry. We are fortunate to have as a member Dr. Eugen Seibold, who is president of the Deutsche Furschungsgemeinschaft, which is the West German equivalent of NSF, and is currently president of the International Union of Geological Sciences. He was very helpful in conveying European attitudes toward scientific drilling to us. The committee was unanimous in agreeing that the potential of the drill for providing significant answers to important scientific questions remains very high and that the program should be continued.

Turning to the platform, three options were considered. The first was to convert *Glomar Explorer* from her present configuration to one more appropriate for scientific ocean drilling. This was the preferred option when the ocean margin drilling program was under consideration, because *Explorer* was large enough to carry and handle the riser necessary for drilling controlled holes in water depths greater than 10,000 feet. It was considerably larger than *Challenger*. It would provide more laboratory space and could carry more participants. Its better seakeeping qualities would allow it to operate in higher latitudes. It did have the disadvantage that it could not pass through the Panama Canal.

However, the ocean margin drilling program has been dropped, and even without the riser conversion, the conversion costs would come to the order of $100 million. Given these heavy costs and in the context of budget projections presented by NSF, the committee was unanimous in its opinion that the *Exployer* was not the appropriate platform for continuation of ocean drilling at this time.

Next the committee considered *Challenger*. *Challenger* has been in service since 1968. If she were to continue in service, even for a few years, she would require overhaul and refit. Even with this refit, she would be a veteran vessel and considerably behind the state of the art of modern drilling vessels. *Challenger* is fully utilized at present, and it would be difficult to find additional laboratory or living space aboard her. This option could be followed if no other were available, but it has clear limitations.

Present conditions in the petroleum industry have produced a third option. There are, at present, four to six modern, dynamically positioned, commercial drilling vessels with the capability of carrying out scientific ocean drilling. Because of the weakness in the market for offshore drilling rigs, it appears that a vessel of this type could be available at this time on very favorable terms. I stress "at this time" because there is no guarantee that the demand for this limited number of vessels will not change in coming months.

These vessels have more space, permitting larger laboratories and more participants. They have greater seakeeping ability than *Challenger*, are more modern, and can handle a longer drill string. Moreover, they can handle risers in water depths up to 6,000 feet. Our committee felt that this option, not available earlier, was the most desirable for continuation of scientific ocean drilling. I was gratified to hear that the chairman of the Conference on Scientific Ocean Drilling, which presented in detail the rationale for continuing drilling in 1981, found this option to be very attractive and noted that it could provide the means for carrying out almost everything suggested in the report. In addition, the chairman of the Joint Oceanographic Institutions' board of governors has also written to indicate the support of the joint institutions for this option.

Finally, I return to the budget context in which this recommendation was made. This is not an inexpensive program, and there are other initiatives in the Earth and ocean sciences that are timely and in which the opportunities and challenges are great. The international phase of ocean drilling has been a classic example of fruitful international cooperation, and a number of countries have participated scientifically and have contributed financially to the program. No contributions were sought for 1984 because of the uncertainties about the future direction of scientific ocean drilling, so NSF budgeted the full cost.

In order to be able to respond to other initiatives in Earth and ocean sciences within the total budget presented, the committee was of the opinion that it should be a goal of the ocean scientific drilling program to obtain at least half of the total funds required trom foreign participants. Dr. Seibold, who is close to the European Community, and through his position in the International Union of Geological Sciences, the world geological community, did not think this goal was unreasonable. It may be difficult to accomplish this in 1984, but it should be achievable in future years.

Thank you.

[The prepared statement of Dr. Drake follows:]

STATEMENT

by

Dr. Charles L. Drake
Dartmouth College
Hanover, New Hampshire

My name is Charles Drake. I am Professor of Earth Sciences at Dartmouth College. I am currently on the Ocean Science and Policy Board of NRC and am President-elect of the American Geophysical Union. I was on the Science Advisory Committee of the Ocean Margins Drilling Program and the Ocean Margin Drilling Advisory Panel of OTA. I was on the Planning Committee of JOIDES from 1964-1968 and was its Chairman from 1966-1968 when Deep Sea Drilling began. Most recently I was Chairman of an Ad Hoc Committee asked by NSF to review plans for ocean scientific drilling in the context of crustal studies.

I thank you for the opportunity to speak to the Subcommittee on the subject of basic research in oceanography. Since my background is in geology and geophysics, I will restrict my comments to these areas and will depend upon my colleagues, Dr. Nierenberg and Dr. Spencer to cover other aspects of oceanography. I will speak to options for scientific drilling in the oceans as well. Ocean drilling is logically considered in the context of crustal studies because the crust of the Earth extends beneath the waters of the ocean as well as beneath the surface of the land. Much of the land surface was created by processes taking place in the oceans. In many ways ocean drilling has more in common with geology on land than it does with other aspcts of oceanography. The same could be said for marine geology and geophysics, but it makes sense to consider these topics in terms of oceanography because common facilities are required to carry out the investigations.

Before I discuss the options for ocean drilling specifically, let me say a few words about crustal studies in general. Geology was a descriptive science for many years; until one knew what was there, it was difficult to devise theories that would adequately explain how it got there or what might happen in the future. Over the years we have explored the surfaces of the continents fairly extensively, although it is surprising how little we know about some areas, even in the United States. We identified the major features and the gross properties of the sea floor. We have not been as successful in exploring the third dimension, that of depth, in any detail because we did not, until recent years, have the tools for detailed remote sensing of the subsurface, nor did we have the funds to apply the drill. Only in regions of direct economic importance, developed mining areas or well drilled sedimentary basins, do we have detailed understanding of the rocks beneath the surface. As examples of the uncertainties, one could cite the recent Beaufort Sea lease sale in which one major company bid 227 million dollars for a particular block and another, equally competent, bid 9 million. Estimates of the total oil reserves of the country using the best available models went from 9 billion barrels in 1922 to between 145-200 billion barrels in 1956, up to almost 600 billion barrels in 1960, to something less than 200 billion barrels today.

This should not be construed to mean that there are vast, untapped supplies of hydrocarbons lurking inside the Earth waiting to be found; rather it should be taken as an indication that we don't know whether there are or not. To be able to make better estimates, we need better models; to produce these models, we must apply the tools of geology, geochemistry, and geophysics to the Earth and we must test these models with the drill.

In recent years, geology has focussed more on processes. This focus was given great impetus by the development of the plate tectonics model which views the earth's outer shell as broken into a small number of very large plates moving relative to each other. The edges of these plates are marked by earthquakes and the movements may be convergent, making mountain systems; divergent, making ocean ridges; or the plates may slide along each other as in the San Andreas fault system of California. Convergent margins are exposed along the edges of continents, as in Alaska or off Washington and Oregon and associated with these areas are earthquakes; volcanoes such as Mt. St. Helens; and processes which concentrate metallic elements. Divergent margins are exposed in the Gorda and Juan de Fuca ridges off Oregon and Washington and these have stirred recent interest because of the polymetallic sulphide deposits that are forming along their axes at rates far faster than might have been estimated from study of similar deposits now on land. The Eastern and Gulf Coasts of the United States appear to have been formed by this plate divergence in the past. Sliding margins are exposed in California and associated with these are the geothermal resources of the Salton Sea area, where active mineralization is also taking place; as well as major destructive earthquakes; and major oil fields.

We are interested in past processes; we explore to see what they have left for us and we try to figure out what they were. We are interested in present processes, because these not only give us some clues that we can apply to the past, they give us some hope of looking into the future; of predicting. Prediction extends beyond anticipation of future events, it also includes the attempt to predict world and national energy, mineral, and environmental resources. If we are to respond to the intellectual challenge of finding out how the Earth works and to the societal need for better information about the Earth, we will have to learn a great deal more about Earth processes and their rates, we will need to examine the Earth in depth, we will have to probe the deep interior which is the course of the heat which drives the processes. We cannot do this only on the land or only in the oceans, or only in the deep interior. We need to look at all of these, and the transition tones between them as, for example, the regions in which the continents and the oceans meet.

The drill is but a tool; it would be a very expensive tool to use for primary exploration, but it may well be the only tool that can be used for confirmation or rejection of models developed from geological, geophysical, or geochemical investigations. It can clarify many uncertainties, and it can reveal many surprises. Scientific ocean drilling provided the confirmation for the model of formation of the ocean crust by seafloor spreading from ocean ridges, a model suggested from geophysical measurements. Drilling demonstrated the presence of salt domes and hydrocarbons in the deepest parts of the Gulf of Mexico. Recent ultra-deep drilling into the basement rocks of the Kola Peninsula of the Soviet Union has reached 11.5 kilometers and is planned for 15 kilometers. The temperature gradients are not at all what one would expect from shallow nearsurface measurements; geophysical discontinuities determined from the surface do not appear to be reflected in the geology at depth; liquids are circulating through the rocks through its entire depth although common wisdom would suggest that the pores should be closed below 10 kilometers; sulphide mineralization was found at depths of over 9.5 kilometers.

When scientific drilling in the deep ocean began, it provided immediate answers to broad scale questions raised by geological and geophysical investigations that could not be answered in any other way. As was the case with the Kola Peninsula hole, the drilling also raised many questions since the cores revealed phenomena that had not been suspected. The drill was a particularly valuable tool in the oceans because their youth and their more limited exposure to fewer thermal or deformational events meant that the data from a limited number of holes could provide answers to questions over a broad area. As the program was matured, more detailed questions can be asked of the drill cores and tools can be placed in the boreholes to make measurements of active processes.

Ocean drilling has been a scientific program from the beginning, but there has been a constant effort to adapt new tools to provide new and better information. We can now reenter holes to probe more deeply and we can place instruments in the holes for in situ measurements. The Hydraulic Piston Corer, first used in 1979, and its recent improvement, the Extending Core Barrel, allow undisturbed samples to be recovered so that the history of the ocean basins, of circulation of the ocean waters, and of the climate above the ocean surface can be better determined. These undisturbed samples have taken on a new significance in the last few years following the suggestions that large extraterrestrial bodies have impacted the Earth, causing massive extinctions of life forms and the replacement of these by new life forms; that evolution of life may be punctuated, rather than gradual; that we may be dealing with the survival of the luckiest, rather than the survival of the fittest.

There is an abundance of life in the near surface waters of the ocean and evidence of this life is found in the sediments in the form of shells or tests of microscopic plants and animals. Only in the sea can the marine record of Earth history be recorded continuously. This record, is drawn on very thin pages; sedimation rates are very slow - on the order of centimeter or so per thousand years. With ordinary rotary drilling and coring, the record is disturbed and the time resolution may be limited to several hundred thousand years. This resolution is sufficient to fill in the history of the Earth in broad strokes, and with a low density sampling scheme. Now we have sufficient information in hand to to target precisely which areas to drill to answer specific questions using The Hydraulic Piston Corer and the Extended Core Barrel. An important opportunity would be lost if ocean scientific drilling were to be terminated.

Specific studies of sea floor processes, such as those acting along continental margins such as the Aleutians, or those on ridges like the Gorda-Juan de Fuca system off the Pacific northwest, will require problem definition and site examination prior to drilling using surface vessels, deep-towed sensors, and even submersibles. Areas of interest have been identified, but additional information will be necessary before the drill is committed. In these areas it will be important not only to recover cores, but also, if we are to understand the nature of the processes, to make downhole measurements.

Now, let me turn to the platform for scientific ocean drilling. The Ad Hoc Committee I chaired was looking at scientific ocean drilling in the context of crustal studies and the committee consisted of a broad mix of geologists, geophysicists, geochemists and oceanographers from academic and industry. We were fortunate to have as a member Dr. Eugen Seibold, President of the Deutsche Furschungsgemeinschaft, the West German equivalent of NSF, and currently President of the International Union of Geological Sciences, who was very helpful in conveying European attitudes towards scientific ocean drilling to us. The committee was unanimous in agreeing that the potential for the drill to provide significant answers to important scientific questions remains very high and that the program should be continued.

Turning to the platform, three options were considered. The first was to convert GLOMAR EXPLORER from her present configuration to one more appropriate for scientific ocean drilling. This was the preferred option when the Ocean Margin

Drilling Program was under consideration, because EXPLORER was large enough to carry and handle the riser necessary for drilling controlled holes in water depths greater than 10,000 feet. It was larger than CHALLENGER, it would provide more laboratory space and could carry more participants and its better seakeeping qualities would allow it to operate in higher latitudes. It did have the disadvantage that it could not pass through the Panama Canal. If the Ocean Margin Drilling Program were still under consideration, with its requirement for drilling through the thick sedimentary cover of Atlantic-type continental margins, EXPLORER would be the most attractive option. However, withdrawal of industrial participation made riser cost prohibitive and even conversion without the riser would require front end costs of the order of 100 million dollars. Given these heavy costs and in the context of budget projections presented by NSF, the committee was unanimous in its opinion that the EXPLORER was not the appropriate platform for continuation of ocean drilling at this time.

Next the committee considered CHALLENGER. CHALLENGER has been in service since 1968; if she were to continue in service, even for a few years, she would require overhaul and refit. Even with this refit, she would be a veteran vessel and considerably behind the state of the art of modern drilling vessels. CHALLENGER is fully utilized at present and it would be difficult to find additional laboratory or living space aboard her. This option could be followed if no other were available, but it has clear limitations.

Present conditions in the petroleum industry have produced a third option. There are at present four to six modern, dynamically positioned, commercial drilling vessels with the capability of carrying out scientific ocean drilling. Because of the weakness in the market for offshore drilling rigs, it appears that a vessel of this type could be available at this time on very favorable terms. I stress at this time because there is no guarantee that the demand for this limited number of vessels may not change in coming months. These vessels have more space, permitting larger laboratories and more participants; they have greater seakeeping ability than CHALLENGER, are more modern, and can handle a longer drill string, but still can transit through the Panama Canal. Moreover, they can handle riser in water depths up to 6000 feet. Our committee felt that this option, not available earlier, was the most desirable for continuation of scientific ocean drilling. I was gratified to hear that the Chairman of the Conference on Scientific Ocean Drilling, which presented in detail the rationale for continued drilling, found this option to be very attractive and noted that it could provide the means for carrying out almost everything suggested in this report. The Chairman of the Board of Governors of Joint Oceanographic Institutions Inc. has also indicated that its member institutions concur with this recommendation.

Finally, I return to the budget context in which this recommendation was made. This is not an inexpensive program and there are other initiatives in the earth and ocean sciences that are timely and in which the opportunities and challenges are great. The International Program of Ocean Drilling has been a classic example of fruitful international cooperation and a number of countries have participated scientifically and have contributed financially to the program. No contributions were sought for FY 84 because of uncertainties about the future direction of scientific ocean drilling so NSF has budgeted the full cost. In order to be able to respond to at least some of these initiatives within the total budget presented, the committee was of the opinion that it should be a goal of the ocean scientific drilling program to obtain at least half of the total funds required from foreign participants. Dr. Seibold, who is close to the European community and, through his position in IUGS, the world geological community, did not think that this goal was unreasonable. It would be difficult to accomplish in FY 84, but it should be achievable in future years.

Mr. WALGREN. Thank you very much, Dr. Drake. We will just continue down the line and come back.

Dr. Nierenberg.

STATEMENT OF WILLIAM A. NIERENBERG, DIRECTOR, SCRIPPS INSTITUTION OF OCEANOGRAPHY

Dr. NIERENBERG. Mr. Chairman and members of the committee, when I began as director of the Scripps Institution of Oceanography in 1965, it was already apparent that the oceans were making a major contribution to the world's food supply. The common fisheries of the world were on their way from an annual catch of about 15 million tons to nearly 80 million. On the one hand, we were beginning to learn a great deal from the failure of the California sardine fishery, and on the other, we helplessly watched the Peruvian anchovetta fishery grow from essentially zero to nearly 14 million tons before it collapsed.

We learned much from the California failure, but we were unable to get it transferred to the Peruvian situation. We learned that short-time climate is primarily an oceanic phenomenon, and we began to develop the primitive capability of prediction. If I may interpolate, Mr. Chairman, I am glad I prepared these notes before you made your earlier remarks. We have used the intervening years to exploit this opening, and the essence of my remarks in this connection is that we have started what will be a long but steady improvement in forecasts.

The initial and still important indicators are the anomalous sea surface temperatures one finds in the north Pacific. To see what is ahead, it is good to review the recent past.

Namias predicted the fateful drought in the U.S.S.R. that prompted the abnormal Russian purchase of grain from the United States that in turn precipitated stringent controls on future grain deals. This was followed by an abnormally severe El Nino that we now know was not unrelated. That event triggered a total collapse of the Peruvian anchovetta fishery that was the principal fish meal supply for mainland China and Japan. Japan, in turn, tried to replace this protein with American soybeans, but President Nixon felt compelled to embargo the crop because of dangerously depleted corn and wheat reserves in this country. This international contretemps need not have occurred if official Washington had paid closer attention to Namias' predictions.

They did so, however, in the next major event, which was at the time of the Arabian oil embargo. The White House used Namias' prediction of a somewhat warmer than normal winter in New England to refrain from issuing ration stamps. The prediction held, and a potentially bad situation was averted. It is now standard procedure to fold short-range climate predictions, as poor as they are at present, into decisions on the national and local level.

With the improvements in research technology and, I must add, a new generation of brilliant oceanographers, the future looks promising. I do not see any sharp breakthroughs, but a steady improvement in predictive capability akin to the impressive achievements in weather prediction. The effects on the economy are enormous. They are so obvious, I do not enumerate them here in this brief statement. The international implications are equally important, particularly to the lesser developed countries who are far more sensitive to periods of excessive drought or rainfall.

The oceans are vast. Man does not live on the oceans and so data comes hard, slow, and extremely variably geographically. Research vessels are essential and must be maintained for process studies, ground truth, and subsurface measurements. However, satellite oceanography is here, and has proven its worth. It is what is required to advance the entire subject by orders of magnitude and hasten the development of climate prediction in particular. My own institution has had a satellite oceanography installation in operation for 3 years that has more than demonstrated the possibilities. Since it is unique, it operates 24 hours a day, 7 days a week, not only for our own physical and biological oceanographers, but also for training and analysis by the armed services.

These extremely promising probabilities are being short-circuited by the lack of an ocean satellite system. Sea Sat was only operational for 99 days. Whatever ocean information is satellite-derived today comes only from those designed for other purposes. I believe that a continuous ocean satellite program is of the highest priority at this time, and the failure to have such an operation is jointly a discredit to the ocean community and the ocean and space bureaucracy of the Federal Government.

I couple the new technical opportunities of improved instrumentation, data management, engineering, and remote sensing with theoretical breakthroughs in physical oceanography that are standing by to be fully exploited. They are two, specifically. The first is the reintroduction of an old idea, "two-dimensional turbulence" which gives the first realistic picture of the development of large-scale disturbances in geophysical fluids.

The second is an extension of Lorenz' seminal work on predictability. It is based on the concepts of strange attractors and bifurcation theory, both of which have become the rage—perhaps over-exploited—of the study of nonlinear phenomena exemplified by weather and climate.

Above all, we have been training and graduating young people of exceptional ability who are at ease with the new technology and new theory. They are fully capable of exploiting whatever resources we put at their disposal, in the form of salaries, platforms, instruments, and advanced computers. I am confident we can accelerate our progress in understanding climate.

I have so far stressed climate as a primary problem, but there are fundamental difficulties remaining with respect to our understanding of the food chain. In too simplistic a view, we held that if a climate change disrupted a major fishery, though the immediate social consequences would be grave, the specific biota would be replaced by an approximately equivalent tonnage, since the general physical and chemical characteristics would be the same. This is what happened when the California sardine fishery failed. It was replaced by an anchovy fishery which, however, never reached full maturity because of institutional inertia.

This is not what happened in the case of the Peruvian anchovetta fishery. It was not replaced by anything resembling its tonnage, and it has become a first-order mystery. It is important that this be unraveled if we are to be better prepared for what will apparently be inevitable major fluctations in food from the oceans.

Our improving ability to deal with the oceans and the corresponding climate change enable us to begin to analyze the consequences of some of our gravest anthropogenically generated global problems. The prime example is fossil fuel generated carbon dioxide. There are many carbon dioxide induced changes that are possible or probable. Among the more important are regionally altered climate patterns, sea level increase, and direct effects of the increased carbon dioxide concentration on flora.

The oceans play the most vital role in this process. First, they are the ultimate sink of the carbon dioxide pulse, and the ocean dynamics and chemistry must be better understood to deal with this problem. Fortunately, there is considerable overlap in needed ocean science for understanding both the carbon dioxide problem and the climate change.

Second, we must be able to pin down more exactly the regional effects of carbon dioxide induced climate change. The atmospheric modelers are having modest success in predicting induced patterns of changed precipitation hydrology, and it is likely this will improve since it is largely computer limited at this time, although better parameterization of fundamental processes is also required.

However, this is not considered of serious portent for the United States by most agricultural scientists. Their consensus seems to be that the gradualism of the climate alteration process will be easily overcome by the genetic improvements they have historically been able to achieve. Figures like 2 percent per annum increase in corn yield, it is felt, will swamp gradual local climate changes. More serious is the higher-order problem of changes in frequency in natural disasters. Examples are numbers of hurricanes per season, frequency of dry year sequences in the Southwest, and frequency of failure of monsoons. Unfortunately, there is at this time no theoretical basis for treating this class of problem.

Sea level rise is obviously an oceanic problem. It no longer seems that the breakup of the western Antarctic ice sheet, with the corresponding catastrophic rise in sea level, is at all likely. However, the induced global warming by carbon dioxide will result in several meters rise in sea level. This rise not only results from the melted Arctic and Antarctic ice but about equally from the resultant thermal expansion of the upper layers of the ocean. This is a serious prediction for many low-lying coastal areas of the world.

Before I leave this subject, I must touch on one aspect of it that is not usually coupled in the same discussion, and that is national defense and world stability. I hold strongly to the opinion that nuclear deterrence depends primarily on our submarine ballistic force. I also believe that our submarine nuclear force is invulnerable for the foreseeable future. Nevertheless, because of the gravity of the matter, it is vital that we know all we can about the physical and chemical character of the oceans, particularly those related to the acoustic properties upon which this invulnerability depends. One development, related to the general class of theoretical breakthroughs I referred to earlier, is a better understanding of oceanic mesoscale eddies, which have profound significance for acoustic antisubmarine warfare.

Changing the subject abruptly, I would like to add just one note to what my colleague, Professor Drake, has prepared on the subject of deep sea drilling and the related marine geology. One unappreciated aspect of the study of marine sediments is the study of ancient climates. It is a subject that now has a name—paleoclimatology. We use it for insights to understanding current climate. More speculative, but with more conventional economic possibilities, are what we can learn from the processes occurring at the continental margins. Sea floor spreading yields a picture of the oceanic sediments that reached the continents and rebuilt them from underneath against the erosion at the surface. It is this erosion, in turn, that forms the oceanic sediments to make a complete, approximately 200 million year, cycle. If we understand these better, we should be able to prospect for ores more efficiently.

Then there is the polar ice. I mentioned it earlier only in terms of something to be melted by climate change. However, the polar caps are an important feedback mechanism in terms of the sharp contrast in reflectivity compared to the rest of the globe. This feedback mechanism is believed to be the cause of ice ages, but in any event is a powerful amplifying agent in climate theory.

Furthermore, coring of the ice yields valuable geochronological information through the gases trapped by the ice. Among others, we have fixed the preindustrial carbon dioxide level which, combined with Keeling's results, give us a picture of the inexorable alteration of our global environment through the use of fossil fuel. We also learn that methane was earlier nonexistent in the atmosphere. This is important, because it is one of the many atmospheric gases of anthropogenic origin whose sum total effect in warming may be equivalent to that of carbon dioxide.

While discussing the Antarctic, we recognize the unusual effects of the circumpolar current, particularly in the upwelling leading to the enormous krill population. This population is estimated as a possible fishery that could match the yield of the rest of the world's fisheries. It is questionable whether this would be an economic source, but if it were, very careful ecological examinations would have to be made.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Nierenberg follows:]

STATEMENT OF
PROFESSOR WILLIAM A. NIERENBERG
DIRECTOR, SCRIPPS INSTITUTION OF OCEANOGRAPHY
BEFORE THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
MARCH 1, 1983

Mr. Chairman and Members of the Committee,

I am William A. Nierenberg, Director of Scripps Institution of Oceanography.

It is always a pleasure for me to present my views on present and future oceanography before an interested and concerned audience. I have appeared before the Congress on and off for over fifteen years and have seen most of the story unfold as we had expected. The future seems even more exciting because of the increased capabilities we have developed to deal with the vast expanses of the oceans.

When I began as Director of the Scripps Institution of Oceanography in 1965, it was already apparent that the oceans were making a major contribution to the world food supply. The common fisheries of the world were on their way from an annual catch of about fifteen million tons to nearly eighty million tons. On the one hand we were beginning to learn a great deal from the failure of the California sardine fishery and on the other we helplessly watched the Peruvian anchovetta fishery grow from essentially zero to nearly fourteen million tons before it collapsed.

We learned much from the California failure but we were unable to get it transferred to the Peruvian situation. We learned that short term climate is primarily an oceanic phenomenon and we began to develop a primitive capability of prediction. We have used the intervening years to exploit this opening, and the essence of my remarks in this connection is that we have started what will be a long but steady improvement in forecasts.

The initial and still important indicators are the anomalous sea surface temperatures one finds in the North Pacific. To see what is ahead it is good to review the recent past.

Namias predicted the fateful drought in the USSR that prompted the abnormal Russian purchase of grain from the United States that precipitated stringent controls on future deals. This was followed by an abnormally severe "El Niño" that we now know was not unrelated. That event triggered a total collapse of the Peruvian anchovetta fishery that was the principal fish meal supply for mainland China and Japan. Japan, in turn, tried to replace this protein with American soy beans, but President Nixon felt compelled to embargo the crop because of dangerously depleted corn and wheat crops. This international contretemps need not have occurred if official Washington had paid closer attention to Namias' predictions.

They did so, however, in the next major event which was at the time of the Arabian oil embargo. The White House used Namias' prediction of a somewhat warmer winter in New England to refrain from issuing ration stamps. The prediction held and a potentially bad situation was averted. It is now standard procedure to fold short range climate predictions, as poor as they are at present, into decisions on the national and local level.

With the improvements in research technology and, I must add, a new generation of brilliant oceanographers, the future looks promising. I do not see any sharp breakthroughs, but a steady improvement in predictive capability akin to the impressive achievements in weather prediction. The effects on the economy are enormous. They are so obvious I do not enumerate them here in this brief statement. The international implications are equally important, particularly to the lesser developed countries who are far more sensitive to periods of excessive drought or rainfall.

The oceans are vast. Man does not live on the oceans and so data comes hard, slow and extremely variably geographically. Research vessels are essential and must be maintained for process studies, "ground truth" and subsurface measurements. However, satellite oceanography is here and has proven its worth. It is what is required to advance the entire subject by orders of magnitude and hasten the development of climate prediction in particular. My own institution has had a satellite oceanography installation in operation for three years that has more than demonstrated the possibilities. Since it is unique, it operates twenty four hours a day, seven days a week not only for our own physical and biological oceanographers but also for training and analysis by the armed services.

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Our improving ability to deal with the oceans and the corresponding climate change enable us to begin to analyze the consequences of some of our gravest anthropogenically generated global problems. The prime example is fossil fuel generated carbon dioxide. There are many CO_2 induced changes that are possible or probable--among the more important are regionally altered climate patterns, sea level increases and direct effects of the increased CO_2 concentration on flora.

The oceans play the most vital role in this process. First, they are the ultimate sink of the CO_2 pulse and the ocean dynamics and chemistry must be better understood to deal with the problem. Fortunately, there is considerable overlap in the needed ocean science for understanding the CO_2 problem and understanding climate change.

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I conclude by stating that other developments await us, particularly in shore processes, beach stabilization and generally the preservation of the coastline against the awesome pressures of a burgeoning population that wants to live by the sea, use it and enjoy it.

Mr. Walgren. Thank you very much, Dr. Nierenberg. It is kind of a good-news/bad-news statement.

Dr. Spencer.

[The biographical sketch of Dr. Spencer follows:]

DEREK WARDLE SPENCER
Geochemist
Senior Scientist
Associate Director for Research
Woods Hole Oceanographic Institution

Birth: May 2, 1934

B.Sc., (Geology), Manchester University, England, 1954
Ph.D., (Geochemistry), Manchester University, England, 1957

Graduate Teaching Assistant, Manchester University, 1956-1957
Geochemist and Supervisor of Geochemical Research, Imperial Oil Ltd., Calgary, Canada, 1957-1965

Associate Scientist, November 1965-1971; Chairman, Department of Chemistry, March 1974-1978; Associate Director for Research, August 1978 to present; Senior Scientist, April 1971 to present, Woods Hole Oceanographic Institution

Member, Geochemical Society, 1959-present
Member, Organic Geochemistry Division of Geochemical Society, 1960-1970 Chairman, 1966-1967
Member, American Association of Petroleum Geologists, 1959-present
Member, Alberta Society of Petroleum Geologists, 1958-1965
Member, American Association for the Advancement of Science, 1968-present
Member, American Geophysical Union, 1974-present

Member, U. S. Screening Committee XV General Assembly, International Union of Geodesy and Geophysics (IUGG), 1968-1969
Consultant on Data Analysis and Statistics, Societe Nationale du Petrole d'Aquitaine, France, 1966-1970
Associate Editor, Geochimica et Cosmochimica Acta, 1970-1974
Member, Geochemical Ocean Section Study (GEOSECS) Scientific Advisory Committee and Executive Committee, 1970-1980
Member, Ocean Sciences Board (formerly Ocean Science Committee), National Academy of Sciences, 1976-1979
Member, post-International Decade of Ocean Exploration (IDOE) Planning Committee of Ocean Sciences Board, 1977-1978
Member, Controlled Ecosystem Pollution Experiment (CEPEX) Steering Committee, 1977-1980
Member, University-National Oceanographic Laboratory System (UNOLS), 1979-present
Member, University-National Oceanographic Laboratory System (UNOLS), Advisory Council, 1979-1980
Chairman, University-National Oceanographic Laboratory System (UNOLS), 1980-present
Consulting Editor in Oceanography, McGraw-Hill Encyclopedia of Science and Technology, 1979-present
Research Interests: Distribution of chemical species in seawater, mathematical modelling and multivariate statistical techniques for use in geochemical problems, factors controlling element distributions in sediments

Author or co-author of 50 scientific publications in geology and geochemistry

STATEMENT OF DEREK WARDLE SPENCER, ASSOCIATE DIRECTOR FOR RESEARCH, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Dr. SPENCER. Mr. Chairman, thank you. My colleagues and yourself in your opening remarks have highlighted some of the important advances that have been accomplished in the last several years in ocean sciences. I would like to say that despite these successes, the academic ocean science community is presently under some stress. I would like to preface my comments with the statement that it is important for those considering the national requirements and priorities for ocean science understand the nature of the science itself.

Oceanography is not a pure discipline, but rather the oceans are a place where pure disciplinary interests and investigations are necessary to understand the processes that have brought the ocean to its present condition and that in the future may keep it in a steady state or allow changes. An oceanographer who is involved in ocean investigations is, first, a biologist, or a chemist, or a physicist, a geologist, or an engineer. But in most of his studies he must interact with his colleagues in several other disciplines for the processes he is investigating rarely recognize the disciplinary boundaries that are imposed by our social and educational systems.

Of necessity, ocean studies must proceed on a broad set of disciplinary fronts, with the boundaries between these fronts being loose and easily crossed. Further, the facilities to support the progress of oceanography must be both versatile to accommodate the varied multi- and interdisciplinary requirements but also on occasion need to be highly specialized to allow new observations or measurements in much narrower disciplinary areas.

Although the conduct of ocean research requires many different facilities, the most prominent and that of most concern to UNOLS is the Academic Oceanographic Fleet. In my written testimony, I have given you details of this fleet. It presently consists of 25 vessels, 12 smaller coastal research vessels and 13 vessels that have the capability of transoceanic voyages. In particular, the larger ships, greater than 200 feet and roughly 2,000 tons displacement, have the range, endurance, and space to meet the diverse needs of the multipurpose scientific operations in all regions of the world's oceans, with the exception of some of the high latitude ice-covered areas. These vessels truly constitute the backbone of the U.S. academic, blue-water, global research fleet. It has been through the use of this larger class of ships that many of the dramatic advances in marine science have been made in the last few decades.

In addition to these general purpose vessels, there are a number of special purpose facilities, including the drilling ship *Glomar Challenger*, the stable platform FLIP, the submersible ALVIN.

Since 1971, the academic fleet has shrunk from a total of 35 vessels to the 25 now listed. In particular, the larger vessels have decreased from eight to six, and the intermediate vessels from eight to seven. The removal of intermediate or large vessels from the fleet because of their greater size and capabilities has a much more pronounced effect on the overall effectiveness and versatility of the fleet than the removal of several smaller vessels. But a reasonable complement of both is necessary for modern oceanographic science.

In addition to this decrease, all operating institutions have experienced difficulty during the last several years in maintaining their ships in first-class operating conditions. There has been equal difficulty in obtaining new modern equipment, such as upgraded winches that can handle the increased demands placed by heavier gear that many experiments now require.

The present status of the oceanographic fleet, is simply a symptom of a larger malaise which affects the whole of academic ocean science, although to different extents in the different disciplinary areas. In the statements that follow, I do not necessarily claim that academic ocean science is in any worse predicament than other sciences or, indeed, many other sectors of our econony at this time.

I believe that the principal causes of our present problems are rooted in several areas, not all of which are independent. Financial support, inflationary increases in costs that have been greater than average inflation increases, competition from industry for high-quality staff, the major growth of Government agencies laboratories conducting both basic and applied ocean research, and increasing difficulties and costs in obtaining clearances to work in foreign waters all contribute.

For my remaining time, I will concentrate on the issue of financial support, for the effects of the other contributing causes, while important, are of somewhat lesser magnitude.

The basic problem is the cumulative effect of inadequate financial support over the past decade. Academic oceanography, because it is a young multidisciplinary science, does not have well-entrenched roots in the academic structure of most universities. There are few undergraduate departments of oceanography, and indeed there should be few, for the progress of the science requires individuals with strong disciplinary backgrounds, together with interests in the broader interdisciplinary areas.

Oceanography is an area of postgraduate and postdoctoral study that has grown principally during and since the Second World War, out of the urgent needs of the U.S. Navy for information on the environment of its operations. As a consequence, oceanography is, perhaps to a greater extent than any science other than biomedicine, dependent on the Federal Government for its growth and support.

Two agencies that have provided long-term base support for academic ocean science are the Office of Naval Research and the National Science Foundation. At the present time, these two agencies supply between 70 to 75 percent of the total academic research funds, with the remainder from State and private resources, and with agencies such as NOAA—Seagrant—DOE, NASA, and USGS, contributing significant but lesser amounts.

ONR and NSF currently support about 80 percent of the cost of the academic fleet operations, with about 70 percent of the funding coming from the National Science Foundation and about 10 percent from ONR. The history of this funding over the last decade or more shows that some substantial changes have taken place. In 1969 to 1970, ocean sciences was the recipient of a substantial increase in funding that accompanied the establishment of the International decade of ocean exploration program at the National Science Foundation. This program continued through the 1970's, and in one way or another, several of the projects have revolutionized the way we think about the ocean and are having a very significant input into the design and the conduct of ocean experiments at this time.

However, the statistics on file at the NSF show that in terms of constant 1972 dollars, and using a standard CPI deflator, a negative growth of about 10 percent from 1973 to 1983 in ocean science research support has taken place. If such a decrease applied to all of the oceanographic funding, and if the CPI deflator did not underestimate the effects of inflation, it could be managed without major disruptions. But unfortunately, neither of these two qualifiers is true.

At about the same time as the onset of IDOE, the ONR basic ocean sciences support started a strong decline. Figures prior to 1972 are difficult to obtain, but in terms of 1972 dollars, ONR core support has decreased substantially. The effect of this decline in ONR funds is particularly evident at two of the leading oceanographic institutions. Information that I have received from Dr. George Shor, associate director at Scripps, shows that from 1970 to 1982, the Scripps Institution of Oceanography has experienced a decrease from 30 percent to 13 percent in its total research support from ONR, and decreases from about 38 percent to 13 percent in its ship support from ONR.

Over the same period, the Woods Hole Oceanographic Institution has seen ONR funding decrease from 56 percent to 25 percent of its total research expenditures, and from 52 percent to about 15 percent of its total ship support. The experience of these institutions is a mirror of the community as a whole.

These losses, which occurred mainly in the early part of the decade, offset many of the gains that came from the IDOE program. Since the mid-1970's, rampant inflation has more than eroded the other gains. The cumulative effect of this erosion is quite profound and is manifest in several areas.

First, the competition for funding from the National Science Foundation is now excessively severe. A scientist submitting a proposal to the ocean sciences division has seen his chances of success decline from about 63 percent in 1977 to 47 percent in 1982. Within the disciplinary areas of ocean science, there is an even greater disparity in the success ratios. An ocean physicist has about a 55-percent chance, while an ocean biologist has less than a 25-percent chance. There are now very many good research proposals that are being declined for lack of funds.

As the ONR funding has decreased, it has quite naturally concentrated in areas of direct and immediate relevance to the Navy mission, and these lie principally within the realm of ocean physics and engineering. The continued support from ONR in these areas has relieved much of the pressure from the National Science Foundation, but other disciplines have not been as fortunate.

The increase in the probability of proposal declines, even for good scientists, is putting some extreme pressure on the oceanographic institutions that employ them. A hiatus in the funding requires an institution to supply salary and research funds that would otherwise be utilized for the support and upgrade of necessary facilities and for the development of new, high-risk innovative programs that are unlikely to survive a somewhat conservative peer review process at the National Science Foundation and are of seemingly little immediate interest to mission agencies.

The low probability of success has a direct feedback to the kind of proposal that is submitted. There are few significant basic research programs that can be started and ended within the period of 1 or 2 years, and a scientist will choose to propose work that can be maintained with some continuity of program. The expense of seagoing work, together with the fact that as ship time is reduced, it is more difficult to assure that a vessel can be at a given place at a given time, augur against the likelihood of funding. Several scientists, because of these factors, because they have been forced to turn to funding from agencies that support little or no ship time, have changed the emphasis of their work from oceanic to coastal, estuary, and terrestrial. This is particularly true for ocean biologists.

Research expeditions in regions remote from U.S. shores are becoming very difficult to plan and execute. A cruise to the southern or Indian oceans must consist of some 10 to 15 or more programs, each occupying 2 to 4 weeks of ship time. In past, such cruises have been away from home port for up to 2 years, but in recent years several of these remote expeditions have been badly disrupted because programs proposed for a given leg have not been funded. This has forced last-minute schedule changes and even temporary lay-ups in foreign ports, both of which are costly and inefficient.

As costs have increased substantially in excess of available funds, there has been a retrenchment in both manpower and facilities. For example, statistics from the oceanography division of the National Science Foundation show that in 1980 they were supporting 20 percent less scientists than in 1975. The funding for new modern laboratory equipment, as well as ship's equipment, has been scarce and has forced the continued use of older, less efficient facilities, with larger and larger amounts of time devoted to upkeep and maintenance.

Ship maintenance has been stretched and delayed, not to the point of seriously compromising vessel safety, but sufficiently to limit the versatility and potential of many vessels.

Perhaps the most significant long-term negative impact is the moral problem caused by working harder and harder for less and less. Although it is difficult to quantify, there is evidence that good productive researchers are leaving academic ocean science, and promising young scientists are not entering. The ocean science community has seen 20 to 25 percent of active researchers in submarine geology and geophysics leave in the last 3 to 4 years. There is growing concern about the lack of new, high-quality graduate students, particularly in ocean physics.

To some extent there are already in existence programs that will alleviate some of the problems, and not all of the retrenchment has been deleterious. For example, some decrease in the size of the academic vessels from 1970 levels is not as harmful as may be supposed. Oceanography has moved from an exploratory science into a science that is asking more focused questions about the oceans.

Many of these questions can be answered with much less at-sea effort.

In addition, improvements in the rate of data acquisition have occurred. Moorings set to collect current velocity and direction data are now routinely deployed for 1 to 1½ years rather than the 2-month period that were common in the early and mid-1970's. Modern geophysical tools, such as multichannel seismic techniques, which allow geophysicists to probe the structure of the subsea floor with high resolution, supply enough data in 1 month to keep a scientist occupied for almost a whole year. With the total complement of ocean science manpower static and in some cases declining for the last several years, these changes in the evolution of science have led to a decreased demand for ships.

However, it is my opinion that the fleet is now at a minimum level for the support of both continued progress on broader multidisciplinary fronts and to allow some thrusts that are essential within the disciplinary areas.

The advent of new technology, such as remote sensing of the ocean surface by satellites, and the remote sensing of the ocean interior by acoustic techniques, will not over the foreseeable future place less demand on ship time. In fact, the reverse is true, for ships will be necessary both to check remote observation techniques while they are in development stages, and to conduct experiments that may allow future extensions of the remote techniques to a greater range of ocean properties.

Recent funding decisions by both ONR and NSF provide a light at the end of the tunnel. In 1980, ONR initiated a series of special research opportunities. Included in these were commitments to mid-life refits and the maintenance of those vessels owned by the Navy, and the DOD initiative announced last year will have an important impact on the quality of tools available for ocean science as well as other areas of scientific endeavor.

These decisions recognize some of the problems and are highly laudable, but they do not tackle the root of the problem, which is support for the conduct of basic research programs at academic institutions. An upgraded and modern vessel is a prime requirement of good ocean research, but it is not particularly useful if scientific programs cannot be developed to use it.

The recently announced ONR special research initiatives for work in the South Atlantic, in the upper ocean atmosphere boundary, and in ocean bioluminescence, which are projected to start in fiscal year 1984-85, promise to provide such support, but they will not do so unless they bring new funds, rather than effect a simple transfer out of the already depleted ONR core program support.

The fiscal year 1984 budget of the National Science Foundation, with its emphasis on basic science support, is similarly most welcome news, although among the larger community of ocean scientists there is naturally some disappointment that the ocean science proposed increase of 9.9 percent is less than half that in other Earth and planetary sciences. However, most realize that initiatives such as ocean drilling and others that will be required in the future do not come without some cost.

Most recognize the major role that drilling can play in the development of our understanding of the history of ocean processes. As the only tool to directly sample the subsea and with the need to develop further knowledge of the structure of ocean basins and continental margins to refine the Earth's recent climatic history and to probe the new crust forming at ocean ridges, drilling is an irreplaceable tool. Nevertheless, any new initiative that would be so costly as to subsume the orderly progress of ocean science on many of the broader multidisciplinary fronts would be detrimental to ocean science and the Nation.

In summary, although the recent sledding has been tough, the present decrease in inflation, combined with the initiatives of ONR and the proposed NSF budgetary increase, offer a considerably brighter future. I hope the Congress will not only fully support the NSF budget for fiscal year 1984 but will also recognize the key role that basic scientific research can play in leading to a higher quality life in both an intellectual and material sense. In this regard, Congress could urge the Navy and other Government agencies with a legitimate ocean interest to recognize and use the resources of our academic oceanographic institutions for the conduct of basic research applied to their missions. Thank you, Mr. Chairman.

[The prepared statement of Dr. Spencer follows:]

TESTIMONY BEFORE
THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
March 1, 1983

Derek W. Spencer
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

My name is Derek Spencer. I am the Associate Director for Research at the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts, one of the leading organizations involved in the practice of oceanographic research and the development of technology for the detection and measurement of ocean properties. I am also the Chairman of UNOLS, the University National Oceanographic Laboratory System, an organization which coordinates the scheduling and, through its member institutions, the operation and composition of the fleet of academic research vessels. I am pleased to have this opportunity to present to you some facts on the status of academic ocean science and, in particular, on the facilities that support the conduct of the science. Oceanographic programs during the last two decades have provided not only tremendous intellectual fodder but have a clear relationship to many of the social, economic and military concerns of this country.

The concept of Plate Tectonics and the proofs subsequently provided by ocean geophysics and drilling have brought us to an understanding of the way that the continents and ocean basins are formed. The patterns of earthquake belts are better understood as are the processes that form mineral deposits within the crust. Ocean drilling has provided the raw material leading to better understanding of the cycles in the earth's climatic history over the last tens to hundreds of thousands of years. These natural cycles are still operating but may be affected by man's increasing industrial activity. Studies by ocean scientists and others have illuminated the increasing presence of man's waste products particularly carbon dioxide in the earth's atmosphere and ocean and studies are presently underway to examine the interaction of the ocean atmosphere system and the role of the ocean in absorbing atmospheric CO_2 which may have relatively short term effects on the earth's climate.

Other studies have used man's products such as radioactive carbon-14 and tritium from atomic weapons testing as tracers of ocean ciruclation processes. These, together with major developments in our understanding of the scales of motion of ocean water are leading us to a position whereby we can comprehend the role of the ocean as a flywheel in the earth's weather and climate system. Studies of water movements in the Antarctic regions have shown the importance of this area as the principal connection between all the deep ocean basins.

The recent discovery of mid-ocean ridge hydrothermal vent regions surrounded by startling oases of life has major implications for ocean mineral resources but they also provide stunning opportunities to examine the role of the deep earth in controlling the composition of the ocean and in understanding the origin of life under conditions quite alien to those normally encountered at the earth's surface.

Recent successes in the use of sound to probe and extract information by remotely sensing water movements in the interior ocean has very significant implications for understanding ocean circulation but also for our submarine defense systems.

These are but a few of the many important advances that have been accomplished in the last several years. But, despite these successes the academic ocean science community is presently under considerable stress.

During my testimony I will offer some opinions on the effects of past and present economic conditions, of government agency policy and actions, and of the changing demands that the science itself has placed upon the facilities needed for its support. These opinions are mine and do not necessarily represent those of the organizations with which I am affiliated.

I would like to preface my comments with the statement that it is important for those considering the national requirements and priorities for ocean science to understand the nature of the science itself. Oceanography is not a pure discipline like chemistry or physics but rather the oceans are a place where pure disciplinary interests and investigations are necessary to understand the processes that have brought the ocean to its present condition and that in the future may keep it in steady state or allow changes. Some processes act slowly and others rapidly, some locally and some globally, some are rather independent and some interact strongly with others. The investigations to unravel the complex set of processes are both intellectually challenging and the results are often of considerable economic and social concern. An oceanographer involved in these investigations is firstly a biologist or a chemist or a physicist or a geologist or an engineer but, in most of his studies, must interact with his colleagues in several other disciplines, for the processes he is investigating rarely recognize the disciplinary boundaries that are imposed by our social and educational system. Of necessity, ocean studies must proceed on a set of broad disciplinary fronts with the boundaries between these fronts being loose and easily crossed. Further, the facilities to support the progress of oceanography must be both versatile to accommodate the varied multi and interdisciplinary requirements but also, on occasion, need to be highly specialized to enable new observations or measurements in much narrower disciplinary areas. The broad range of disciplinary and interdisciplinary programs together with the fact that many of the individual disciplines are at a different stage in the evolution of their understanding puts great emphasis on the continuing need for versatile and specialized facilities that are adequate to keep progress moving on a broad front but allow thrusts
in some specific areas that could lead to major new breakthroughs in our understanding of the ocean as a whole system. The diverse nature of the science of oceanography, particularly in times of economic stress, must of necessity lead to disagreement on the priorities that should be assigned to costly major new thrusts when they may impact on the scarce resources necessary to keep progressing at a minimal level on a broad front.

It is important to realize that agreement between a biologist and a physicist on the importance of the next ocean experiment is somewhat, but, not much more likely than agreement between a democrat and a republican on a social program. Where the outcome of a decision is uncertain, indeed often unknowable, each approaches it from the equally valid but different perception of his own training and experience. But, just as democrats and republicans are essential to the functioning of our democratic system so are biologists, physicists and members of other disciplines essential to the functioning of oceanography. If this country wishes to keep a leadership position in ocean science it must recognize and support both the multi-disciplinary and the interdisciplinary aspects of the science.

Although the conduct of ocean research requires many different facilities, the most prominent and that of principal concern to UNOLS is the Academic Oceanographic Fleet. The composition of the fleet and some of its characteristics are outlined in Table 1. The vessels range in size and capabilities from less than 65 feet in overall length and less than 100 tons displacement to greater than 200 feet and about 2000 tons displacement. The smaller ships (less than 100 feet) have very limited laboratory and berthing space and are incapable of handling heavy gear or of operating in deep water. These vessels carry minimum crews and are generally unsuited for other than short cruises or on-station activities of several days in clement regions. They operate principally in a "day boat" mode, carrying about five to eight scientists and students for studies in near coast waters and estuaries. The ships in the size range from 100 to 150 feet have increased capabilities. They have modest berthing, laboratory and storage space and are equipped for certain deep sea operations but have very limited sea-keeping attributes and are used predominantly for short cruises in the coastal and continental shelf regions of the United States. The intermediate vessels, from 150 to 200 feet, have moderate range and endurance and berthing for about fifteen scientists. While possessing the capability to perform transoceanic voyages, they are limited by berthing, storage, laboratory space and sea-keeping from performing many multipurpose and extended expeditionary work. However, they are efficient and cost effective for regional, shorter range, multipurpose tasks and for some extended range single purpose tasks. The larger ships, greater than 200 feet, have range, endurance and space to meet the diverse needs of multipurpose scientific operations in all regions of the world's oceans with the exception of high latitude, ice covered areas. These vessels constitute the backbone of the U.S. academic, blue-water, global research fleet. It has been through the use of ships of this class that many dramatic advances in marine science have been made in the past few decades. In addition to these general purpose vessels there are special purpose facilities that are operated by some academic institutions. These include the drilling ship GLOMAR CHALLENGER, the stable platform FLIP, and the submersible DSRV ALVIN.

The academic fleet has shrunk from a total of 35 vessels in 1971 to the 25 that are now present and listed in Table 1. In particular the larger vessels have decreased from eight to six and the intermediate vessels from eight to seven. The removal of intermediate or large vessels from the fleet, because of their greater size and capabilities, has a much more pronounced effect on the overall effectiveness and versatility of the fleet than the removal of several small vessels but a reasonable complement of both is necessary for modern oceanographic science. In addition to this decrease, all operating institutions have experienced difficulty during the last several years in maintaining their ships in first class operating condition. There has been equal difficulty in obtaining new modern equipment such as upgraded winches that can handle the increased demands placed by the heavier gear that many experiments now require. A further trend is to increased specialized use of significantly large fractions of the ship time available on the large vessels. As an example, the R/V ATLANTIS II, an excellent multipurpose, long range and endurance vessel is being converted to a mother-ship for the submersible DSRV ALVIN. The current mother-ship, the R/V LULU is small and for many years has hampered the scope of submersible science programs which will now benefit greatly from the increased range, laboratory facilities and hotel capacity of the larger vessel. While the R/V ATLANTIS II will keep all of the capabilities that make her an excellent general purpose ship, the specialized needs of the submersible programs will undoubtedly drive most of her operating schedule with a consequent decrease in the time available for other programs. At this time several factors are contributing to make it increasingly difficult to conduct oceanograhic research in areas remote from U.S. shores and I will elaborate further on these later in my testimony.

The demise of the Academic Fleet is but a symptom of a larger malaise that affects the whole of academic ocean science though to different extents in the different disciplinary areas. In the statements that follow I do not claim that academic ocean science is in any worse predicament than other academic sciences or indeed than many sectors of our economy at this time. It is my belief that the principal causes of the present problems are rooted in several areas some of which are not independent of each other.

1. Financial support.
2. Inflationary increases in costs that have been greater than average inflation rates.
3. Competition from industry for high quality staff.
4. A major growth of government agency laboratories conducting both basic and applied ocean research.
5. Increased difficulties and costs in obtaining clearances to work in foreign waters.

For most of my time remaining I will concentrate on the issue of financial support for the effects of the other contributing causes, while important, are of somewhat lesser magnitude.

A basic problem is the cumulative effect of inadequate financial support over the past decade. Academic oceanography, because it is a young multidisciplinary science does not have well entrenched roots in the academic structure of most universities. There are few undergraduate departments of oceanography and indeed there should be few, for the progress of the science requires individuals with strong disciplinary backgrounds, together with interests in broader interdisciplinary areas. Oceanography is an area of postgraduate and postdoctoral study that has grown principally during and since the second World War out of the urgent needs of the U.S. Navy for information on the environment of its operations. As a consequence, oceanography is, perhaps to a greater extent than any science other than bio-medicine, dependent upon the Federal Government for its growth and support.

The two agencies that have provided long term, basic support for academic ocean science are the Office of Naval Research (ONR) and the National Science Foundation (NSF). At the present time these two agencies supply between 70% to 75% of the total academic ocean research funds (about 50% NSF and 25% ONR) with the remainder largely from State and private sources. Agencies such as NOAA (Sea Grant), DOE, NASA and the USGS contribute significant but lesser funds and although it is difficult to obtain accurate figures it appears that somewhat less than 2% of academic ocean research receives industry support. The same two agencies are currently supporting about 80% of the costs of the academic fleet operations (70% NSF and 10% ONR). The history of this funding over the last decade or more shows that substantial changes have taken place. In 1969-70 ocean sciences was the recipient of a major increase in funding that accompanied the establishment of the International Decade of Ocean Exploration (IDOE) Program at the NSF. Initially about $15 million increasing to about $22 million in 1972-73 enabled the ocean sciences community to mount several major inter-institutional programs many of which, in one way or another, have revolutionized the way that we think about the ocean and are having a very significant input into the design and conduct of ocean experiments at this time. However, statistics on file at the NSF show, in terms of constant 1972 dollars and using a standard CPI deflator, a negative growth of about 10% from 1973 to 1983 in ocean research support and about an 8% decrease in the sum of ocean facilities and research support. Such decreases, if they applied to the total funding of ocean science and if the CPI deflator did not underestimate the effects of the inflation that has occurred, could be managed without major disruptions. Unfortunately, neither of these qualifiers is true. At about the same time as the onset of IDOE the ONR support of basic ocean sciences started a strong decline. Figures prior to 1972 are not obtainable but, in terms of 1972 dollars, ONR's core contract research program which supports mostly academic institutions, declined from $21 million in 1972 to about $15 million in 1975. It is currently somewhat less than $15 million after rising to $17 million in 1980. The effect of the decline in ONR funds is particularly evident at two of the leading oceanographic institutions. From 1970 to 1982 the Scripps Institute of Oceanography has experienced a decrease from 30% to 13% in its total research support from ONR and a decrease from 38% to 13% in ship support. Over the same period, the Woods Hole Oceanographic Institution has seen ONR funding decrease from 56% to 25% of its total research expenditures and from 52% to about 15% of its total ship support. The experience of these institutions is a mirror of the whole community which, during the 1970's, has seen ONR contributions to its total research support decline from over 30% to less than 10% with ONR ship operations support decreasing from 32% to about 10%. These losses which occurred mainly in the early part of the decade offset many of the gains from the IDOE Program and since the mid 1970's rampant inflation has more than eroded the other gains.

The cumulative effect of this erosion has been profound and is manifest in several areas:

1. The competition for funding from the NSF is now excessively severe. Almost all academic ocean science is performed as a result of proposals submitted to government agencies. A scientist submitting a proposal to the Ocean Sciences Division has seen his chances of success decline from 63% in 1977 to 47% in 1982. (This compares with 1982 ratios of from 52% to 62% in the other divisions of the AAEO directorate at NSF). Within the disciplinary areas of ocean science there is even greater disparity in the success ratios. An ocean physicist has about a 55% chance while an ocean biologist has less than a 25% chance. There are now many very good research proposals being declined for lack of funds. As ONR funding has decreased it has, naturally, concentrated in areas of direct and immediate relevance to the Navy mission and these lie principally within the realm of ocean physics and engineering. The continued support from ONR in these areas has relieved much of the pressure from the NSF but other disciplines have not been as fortunate. It is now almost impossible for an active ocean scientist to maintain a productive program on a single grant or contract. Most have two or three and some, if they direct a large research group, as many as six or eight. With the success ratios as they are, it is difficult for a scientist to survive without writing four to ten or more proposals per year. When one includes the time to write these proposals and the time spent in reviewing the proposals of others, the total amounts to a horrendous tax on the productivity of the community.

2. The increase in the probability of proposal declines even for very good scientists is putting extreme pressure on the oceanographic institutions that employ them. A hiatus in funding requires an institution to supply salary and research funds that would otherwise be utilized for the support and upgrade of necessary facilities and for the development of new high risk innovative programs that are unlikely to survive the conservative peer review process of NSF and are seemingly of little immediate interest to mission agencies.

3. A low probability of success has a direct feedback to the kind of proposal that is submitted. There are few significant basic research programs that can be started and ended within a period of one or two years and a scientist will choose to propose work that can be maintained with some continuity of program. The expense of sea-going work together with the fact that, as ship time is reduced, it is more and more difficult to assure that any vessel can be at a given place at a given time (a condition of many ocean experiments) and that the reporting of scientific results may often be delayed by extensive cruise logistics, observation and measurement all augur against the likelihood of funding. Several scientists, because of these factors and because they have been forced to turn to funding from agencies that support little or no ship time have changed the emphasis of their work from oceanic to coastal and estuarine. This is particularly true for ocean biologists.

4. Research expeditions in regions remote from U.S. shores are becoming very difficult to plan and execute. A cruise to the Southern or Indian Oceans must consist of up to ten or fifteen or more programs each occupying two to four weeks of ship time. In the past, such cruises have been away from a home port for up to two years. In recent years several of these remote expeditions have been badly disrupted because programs proposed for a given leg have not been funded. This has forced last minute schedule changes and even temporary lay ups in foreign ports both of which are costly and inefficient. Such difficulties could be avoided by planning starting some two to three years ahead of the operating year. However, many scientists resist the early submission of proposals because a later proposal is almost always more complete and is likely to be more competitive. Similarly, because of the annual cycle of Federal funding and because they have an obligation to support the best science proposed with limited funds, agency program managers are reluctant to make early commitments. The net result is that we have seen a marked decline in expeditions to remote areas.

5. As costs have increased substantially in excess of available funds, there has been retrenchment in both manpower and facilities. For example, statistics from the Oceanography Division of the NSF show that in 1980 they were supporting 20% less scientist time than in 1975. Funding for new modern laboratory equipment as well as ships' equipment has been scarce and has forced the continued use of older less efficient facilities with larger and larger amounts of time devoted to upkeep and maintenance. Ship maintenance has been stretched and delayed, not to the point of seriously compromising vessel safety, but sufficiently to limit the versatility and potential of many vessels.

6. Perhaps the most significant long-term negative impact is the morale problem caused by working harder and harder for less and less. Although it is difficult to quantify, there is evidence that good productive researchers are leaving academic ocean science and promising young scientists are not entering. The ocean science community has seen 20% to 25% of active researchers in submarine geology and geophysics leave in the last three years and there is growing concern about the lack of new high quality graduate students, particularly in ocean physics.

To some extent there are already in existence programs that will alleviate some of the problems and not all of the retrenchment has been deleterious. For example, some decrease in the size of the academic fleet from 1970 levels is not as harmful as may be supposed. Following the second World War oceanography as a developing discipline was very largely an exploratory science. We had to find out "what the ocean is" before we could start to ask questions about "why it is". The exploratory mode continued through into the 1960's and then, as more data became available, there has been a gradual transition to more focused programs asking specific questions about ocean phenomena. Many of these questions can be answered with less at- sea effort. In addition, improvements in the rate of data acquisition have occurred. Moorings set to collect current velocity and direction data are now routinely deployed for 1 - 1 1/2 years rather than for the two month periods that were common in the early and mid 1970's. Modern geophysical tools such as multichannel seismic techniques which allow geophysicists to probe the structure of the subsea floor with high resolution supply enough data in one month to keep a scientist occupied for a whole year particularly with the computer facilities that are available. With the total complement of academic ocean science manpower static and in some cases declining for the last several years, these changes and the evolution of the science have led to a decreased demand for ships.

It is, however, my opinion that the fleet is now at a minimum level for the support of both continued progress on broader multidisciplinary fronts and to allow some thrusts that are essential within the disciplinary areas.

The advent of new technology such as remote sensing of the ocean surface by satellites and the remote sensing of the ocean interior by acoustic techniques will not, over the foreseeable future, place less demand on ship time. In fact the reverse is true, for ships will be necessary both to check remote observation techniques while they are in development stages and to conduct experiments that may allow future extensions of the remote techniques to a greater range of ocean properties. In any event, the delays in approval of ocean satellites indicate that their common use as ocean sensing tools is unlikely before the turn of the century.

Recent funding decisions by both ONR and NSF provide "a light at the end of the tunnel". In 1980 ONR initiated a series of special research opportunities. Included in these were commitments to midlife refits and maintenance for those vessels owned by the Navy and the DOD Instrumentation Initiative announced last year will have an important impact on the quality of tools available for ocean science as well as other areas of scientific endeavor. These decisions recognized some of the problems and are highly laudable but they do not tackle the root of the problem which is support for the conduct of basic research programs at academic institutions. An upgraded and modern vessel is a prime requirement of good ocean research but it is not particularly useful if scientific programs cannot be developed to use it.

The recently announced ONR Special Research Initiatives for work in the South Atlantic, in the upper ocean/atmosphere boundary and in ocean bioluminescence, which are projected to start in Fiscal 84 to 85, promise to provide such support but they will not do so unless they bring new funds rather than effect a simple transfer out of the already greatly depleted ONR core program support.

The Fiscal 84 budget of NSF with its emphasis on basic science support is similarly most welcome news although among the larger community of ocean scientists there is, naturally, some disappointment that the ocean sciences proposed increase of 9.9% is less than half of that in other earth and planetary sciences. However, most realize that initiatives such as ocean drilling and others that will be required in the future do not come without some cost. Most recognize the major role that drilling can play in the development of our understanding of the history of ocean processes. As the only tool to directly sample the subsea and with the need to develop further knowledge on the structure of ocean basins and continental margins, to refine the earth's recent climatic history and to probe the new crust forming at ocean ridges drilling is an irreplaceable tool. Nevertheless, any new initiative that would be so costly as to subsume the orderly progress of ocean science on many of the broader multidisciplinary fronts would be detrimental to ocean science and the nation.

There is a growing recognition among academic ocean scientists that in the likely economic conditions of the future, we must learn to order new major thrusts. Owing to the diversity of the community this will not be an easy task but the process has started. Its development must be nurtured by community leaders and community organizations such as JOI and UNOLS but also by the National Academy of Sciences and government agencies if this nation is to maintain a leadership role in the development of ocean knowledge and assessment of its potential utilization in future years.

Although problems with funding and inflation have been the major concerns of academic oceanographic institutions other factors have not been negligible. In particular, salary and somewhat limited opportunities due to funding restrictions have provided many institutions with difficulty in hiring high quality staff. This is true particularly in the areas of geology and geophysics where there has, in fact, been a net movement of established productive researchers into the oil industry. Competition for graduate students has been particularly severe. Other areas where academic institutions have been at a disadvantage are physics, electronics and engineering. However, the current economic situation and the decreased inflation are already producing significant increases in the applications from high quality students and scientists.

Some difficulties have arisen from the major growth of government agency in-house laboratories during the last decade. Although the applied needs of many mission agencies must be met by their own staff, many have also turned their basic research programs inwards. This is particularly true of agencies such as NOAA and EPA but also to lesser extents with DOE and ONR. Where academic basic research programs have existed the continuity of the programs has often been threatened or disrupted by variations in the funding and the protection of in-house interests.

A problem that is apparently growing is the increased difficulties that are arising in obtaining clearances to work in foreign waters. Some 42% of the world's ocean lies within the 200 mile limit of a country. The recognition of the potential of its marine realm is growing in many countries. They wish, and indeed have the right, to ocean scientific research information produced within their own borders. As a consequence more detailed clearance requests and more stringent reporting procedures are being demanded before clearances are issued and foreign observers on research cruises are now quite common.

These conditions are not of great concern but they do increase costs. A greater problem for U.S. marine science emerges from the U.S. stand in the Law of the Sea Treaty. This is the subject of several continuing considerations in sections of the marine community, funding agencies and the State Department.

In summary, although the recent sledding has been tough, the present decrease in inflation combined with the initiatives of ONR and the proposed NSF budgetary increase offer a considerably brighter future. I hope that the Congress will not only fully support the NSF budget for Fiscal 1984 but will also recognize the key role that basic scientific research can play in leading to a higher quality of life in both an intellectual and material sense. In this regard the Congress could urge the Navy and other government agencies with legitimate ocean interests to recognize and use the resources of our academic oceanographic institutions for the conduct of basic research applied to their missions. The country, the agencies, the institutions and the scientists would all benefit.

TABLE 1

THE ACADEMIC RESEARCH FLEET

Data From Current Ship Operating Proposals (6/30/82)

SHIP	OPERATING INSTITUTION	LOA (FT)	DISPLACMNT (TONS)	YEAR BUILT	NUMBER SCIENT	NUMBER CREW	RANGE (NM)	ENDURANCE DAYS	1982 OPERATING COSTS (K$)
GREATER THAN 200 FEET									
Knorr	WHOI	245	1915	1969	25	24	10,000	45	3,000
Melville	Scripps	245	2075	1970	29	23	9,000	45	3,000
Thompson	U. Wash.	209	1302	1965	19	22	8,000	40	2,200
Atlantis II	WHOI	210	2300	1963	25	24	13,500	45	3,000
Conrad	LDGO	209	1370	1962	19	20	10,000	60	2,200
T.Washington	Scripps	209	1362	1965	19	23	9,000	35	2,500
150 - 200 FEET									
Endeavor	URI	177	962	1976	16	12	7,000	30	1,600
Gyre	TAMU	174	950	1973	20	10	11,000	42	1,600
Iselin	RSMS	170	830	1972	15	12	12,000	30	1,600
Kana Keoki	U.Hawaii	156	900	1967	16	12	10,000	42	1,100
New Horizon	Scripps	170	770	1978	13	12	6,000	30	1,600
Oceanus	WHOI	177	960	1975	12	12	7,000	30	1,600
Wecoma	OSU	177	1015	1975	16	12	7,500	30	1,600
100 - 150 FEET									
Alpha Helix	U.Alaska	133	554	1966	15	9	6,500	30	1,400
Cape Florida	RSMS	135	539	1981	12	9	7,680	21	1,200
Cape Hatteras	Duke/UNC	135	539	1981	12	10	6,800	24	800
Velero IV	USC	110	650	1948	12	11	5,500	18	700
Cape Henlopen	U. Del	120	179	1976	12	7	2,560	14	--
LESS THAN 100 FEET									
Cayuse	MLML	80	173	1968	8	7	4,500	20	600
E.B.Scripps	Scripps	95	234	1965	8	5	5,100	14	700
R.Warfield	CBI	106	162	1967	10	7	1,200	14	700
Blue Fin	Skidaway	72	86	1972	8	5	2,660	15	150
Calanus	RSMS	64	111	1971	6	2	2,500	14	300
Longhorn	U.Texas	80	172	1971	10	5	2,000	20	350
Barnes*	U. Wash	65	--	--	--	--	--	--	--
								Total Costs	33.8

* The R/V BARNES, a former Coast Guard vessel, has been added recently by negotiation between NSF and GSA.

Mr. Walgren. Thank you very much, Dr. Spencer. It seems that is analogous to the instrumentation problem in other areas of education. I know that is a balancing act that is just going to have to be gone through.

Your comment about new initiatives that might be so costly as to subsume the support for basic research would be extremely detrimental, do we anticipate those new initiatives at this point. Can you see them coming?

Dr. Spencer. Mr. Chairman, I would believe that the particular issue that we have been considering here as far as ocean drilling is concerned could possibly have done so. The alternative that has been proposed for a commercial drilling vessel appears to be very reasonable. This appears to be an appropriate time. The levels of support that are being requested for an ongoing drilling program, particularly with the possibility of some 50 percent of the support coming from foreign contributors are acceptable and, at that level ocean drilling is a bargain. Cost at the level that may have been necessary for the *Explorer,* particularly if they had all been put against ocean sciences, are untenable.

Mr. Walgren. Just so that I understand, we are proceeding at less of a level than anticipated under *Explorer*; is that correct, Dr. Drake?

Dr. Drake. The *Explorer,* as Dr. Knapp said, would have frontend costs on the order of $90 million or so. If you spread this over 10 years, that number is not so excessive. If you spread it far enough, the cost of the *Explorer* does not seem to be as high as if you deal with it for a shorter period of time. The front-end cost to equip a commercial vessel or to refurbish *Challenger* are more or less comparable and considerably less, like 10 percent of the cost of converting the *Explorer.*

Mr. Walgren. Ten percent of the total?

Dr. Drake. Yes.

Mr. Walgren. What do we give up by giving up the *Explorer*? You indicated that the first scientific choice would be the *Explorer,* but given budget constraints another vessel might be a better choice.

Dr. Drake. One of the major reasons the *Explorer* was considered in the first place was for the ocean margin drilling program. The concept of this program was one in which industry would contribute half and the Government itself would contribute half. That was a very expensive program, because it meant engineering costs of developing and building riser and then being able to handle riser in very deep water, considerably deeper than it has ever been handled before. So it was a major technological development job, as well as a very expensive proposition.

What we would lose would be the ability to drill controlled holes in deep sediments and water over 6,000 feet deep. But I go again to the chairman of the COSOD report, the Conference on Scientific Ocean Drilling, who took note of the fact that almost everything that they propose as a scientific challenge the drill could be applied to could be done on the vessel we are talking about.

Mr. Walgren. Is there a report—perhaps that is the one—that tries to relate these various research opportunities in the Earth and its crust?

Dr. **Drake**. You referred to a report before. There was a preliminary report, which I believe is in the hands of the National Science Foundation, from the Geological Sciences Board, and there is a more detailed report under preparation which should be completed very soon. I sit on that committee as well as this other one, so I know what the major thrusts are in that report. The major thrusts in that report included most of the things that were discussed by the ad hoc committee that I dealt with. Because that report was responding specifically to the earth sciences division, rather than both earth and ocean sciences, there were some things like paleoceanography, paleoclimatology, the use of the hydraulic piston corer, and so forth that were not specifically in that report; but that should be forthcoming in the near future.

I should also note that there are about a dozen reports which are related to crustal studies, ocean drilling, and what have you. There is no disagreement among any of these reports about the major thrusts. Each of the committees that examine the situation had a slightly different charge and responded to the specific charge. But if you look for the common ground, you find that it is indeed there; we are not going off in a bunch of directions, and there are a number of very specific thrusts that are common to all these reports.

Mr. **Walgren**. Dr. Nierenberg, you talked about climate. It struck me that there was some indication that the ocean sciences division may not be as climate oriented—and I do not know that for a fact, but the suggestion has been made, as it ought to be. Is there some comment you can make in that area?

Dr. **Nierenberg**. I do not know if I can make a useful one. We are certainly oriented that way. I really am unable to separate ocean climate from atmospheric climate. They are one and the same.

Mr. **Walgren**. But is NSF oriented in the right way?

Dr. **Nierenberg**. The answer, I suppose, is yes and no. Now you get us into an interdisciplinary argument. I think the ocean NSF is. I think they understand fully, even though they do not necessarily articulate it, because physically oceanography is supported essentially on the basis of uncovering what is needed in oceanic climate.

As an example, they are dealing with mesoscale eddies and structure of the upper oceans, and related questions.

I think the problem is more not so much bureaucracy as it has been the disciplines. My distinguished colleagues call themselves meteorologists have, for many years, been very slow in recognizing the fact that the origin of their subject is in the oceans. It is a complicated subject. They are now. I just sat in a meeting of the climate board of the National Academy of Sciences, and I was quite surprised to hear how much discussion was taking place with regard to oceanic measurements.

I think the problem is always money. I really referred to it in a very elliptic and condensed version of what I would want to say more. I think the problem comes out that we live on land, and actually a great bulk of the data that is used by atmospheric scientists are measurements that are made for other purposes. They are not made for meteorology. I am a pilot myself, and I know that about 90 percent of the temperature measurements are made for landing airplanes at airports at the level of the airplane and for keeping airplanes from colliding at altitude. Those form a tremendous bank of numbers that are used by the atmospheric scientists.

The weakness is, of course, they are not made over the ocean. Making the same measurements over the ocean are very expensive for the same density of observations. That is a really fundamental weakness, and the only way out of it is to pay the price and make the measurements. The disparity is not as great as it would seem. Even atmospheric scientists make do with what they can get.

Please recall that I made my complaint earlier about the fact that we do not have an oceanic satellite, so we are using the measurements from satellites that are being made for other purposes, such as Landsat, meteorological satellites and so on. In the same way, meteorologists have to use measurements that are made for other purposes. So there is a natural diversion of attention in that direction, and that has been most unfortunate.

I have no complaint really, even though I am very advocate of the subject, as you can see, about the focus of the oceanic division of the National Science Foundation. They perhaps could be more explicit and articulate, but it would not get them more money, do I think, to do what they have done.

Mr. **Walgren**. Do you folks see opportunities for research along the lines that Dr. Cousteau was suggesting, where you can integrate the human factors with the finite physical data that you are looking at?

Dr. **Nierenberg**. Mr. Chairman, you people sitting on the other side are much more expert in integrating those factors than we are when it comes right down to it. I sit on committees. I am the chairman of the carbon dioxide committee, authorized by the Congress, working through the National Academy of Sciences. I am sitting on a peer review committee that The White House has asked me to do for the joint Canadian-American acid rain problem, for example and that teaches me that that is the most difficult part of the problem. Exactly how you do research on that class of problem is very difficult indeed. I do not know what my colleagues might say about it.

Dr. **Drake**. I agree totally. One of the difficulties we all face is that you are dealing with one world, as Cousteau said, yet in order to handle it we have to divide it up into packages. We have this problem at universities, getting departments to work together because each department tends to get focused on its own discipline—and rightly so—and to neglect the interfaces with other disciplines. It is a terrible problem. I agree with Cousteau on that. It is a very difficult one to handle.

Dr. **Spencer**. If I might add, Mr. Chairman, I think it would be very difficult at this time to propose a specific program that one could be confident would lead to major progress in the interrelationships between many of the disciplinary areas that Captain Cousteau was talking about. This does not mean, however, that there is not some progress being made toward these objectives.

Many oceanographic institutions at this time have somewhat small programs in the areas of marine policy and ocean management, where economists, lawyers, anthropologists, and other individuals are at an institution working with the marine scientists and considering the implications of marine science in areas beyond the traditional boundaries. I still think, however, we have a long way to go before we reach the idea that Captain Cousteau was talking about.

Dr. NIERENBERG. If I could make one last pessimistic remark on the subject, I agree completely with Dr. Spencer. We are making that effort, and I think that the major oceanographic institutions could very well be proud of their record for recognizing the problem a long time ago, the one that was mentioned by Jacques Cousteau. We have even invested our own money starting institutes and organizations of the kind he describes.

As I look back at the last 15 years of our efforts and the efforts of other groups, while we have some successes in certain areas, I just see the gap widen. In other words, I think we are losing ground. The problems are coming at a rate and an intensity that seems faster than—let me use the word loosely—our social science ability seems capable of coping and developing.

I have consulted with some colleagues and sociologists, whom I respect a great deal. They have given me the impression that they have the same feeling in much broader areas of human endeavors.

Mr. WALGREN. That would indicate that there is an effort in the social sciences that has to be made.

I would like to recognize the gentleman from New Hampshire, Mr. Gregg.

Mr. GREGG. Thank you, Mr. Chairman. I want to apologize to our distinguished panel for being unable to be here for the core of your testimony, if I may use that term. I especially appreciate Dr. Drake being here, an honored scholar from Dartmouth College in New Hampshire. Our chairman also is one of Dartmouth's finest, and we are very lucky to have so many high-quality people participating in the Government today from Dartmouth.

I just want to emphasize that I will look forward to reading the presentations of the panel and that I support the ocean drilling programs and wish you success in continuing these programs. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Gregg. There are a lot of small institutions out there, and there are some of us who like them very much, and we do not want to see them overwhelmed by others.

Dr. DRAKE. I think Daniel Webster said that.

Mr. WALGREN. Thank you very much. We appreciate your presence.

The last witnesses—and I apologize for the time that has gone by—are Dr. George Field, chairman of the National Academy of Sciences, Committee on Astronomy, and Dr. Arthur Code, president of the American Astronomical Society.

We will start with Dr. Code, if we can. Again, written statements will be made part of the record. Please summarize or proceed with some dispatch in view of the hour; but we are here to listen to you, so please proceed.

[The biographical sketch of Dr. Code follows:]

Biographical Sketch
Arthur D. Code

Born August 13, 1923, Brooklyn, New York. Ph.D. (Astronomy and Astrophysics) University of Chicago, 1950. Instructor in Astronomy, University of Virginia, 1949-50. Instructor, University of Wisconsin 1950-52; Assistant Professor, 1952-56; Associate Professor of Astrophysics, California Institute of Technology and Staff Member, Mount Wilson and Palomar Observatories, 1956-58; Professor of Astronomy, Director of Washburn Observatory, and Chairman of Department of Astronomy, University of Wisconsin, 1958-70; Joel Stebbins Professor of Astronomy, University of Wisconsin 1970-80; Hilldale Distinguished Professor, University of Wisconsin 1980- . Visiting Astronomer Kitt Peak National Observatory, 1967 and 1969, Cerro Tololo Inter-American Observatory 1979. Acting Director Space Telescope Science Institute 1981.

Research interest include spectrophotometry of stars and galaxy, radiative transfer theory, and ultraviolet space observations of stars and galaxies. Code was principal investigator for the Orbiting Astronomical Observatory (OAO-2). The OAO was launched December 7, 1968, the first optical observatory in space, and functioned successfully for more than four years, returning much new data on the brightness of planets, stars, and galaxies in the ultraviolet. He is author of approximately 100 scientific papers on research in astrophysics and space astronomy.

He has served on a variety of national committees and panels including the NASA Astronomy Missions Board, and served as Chairman of the Board of Directors of AURA, Inc. (which operates the Kitt Peak National Observatory) from 1978-80. He is currently the President of the American Astronomical Society. A member of the U.S. National Academy of Sciences, American Academy of Arts and Sciences and the International Academy of Astronautics. Code was the recipient of the NASA Public Service Award in 1970, and the Professional Achievement Award, University of Chicago Alumni Association in 1971.

STATEMENT OF ARTHUR D. CODE, PRESIDENT, AMERICAN ASTRONOMICAL SOCIETY

Mr. CODE. Thank you, Mr. Chairman.

During the last two decades, astronomy has witnessed an unprecedented growth of discovery and exciting ideas, the roots of which lie in our ability to explore the entire electromagnetic spectrum, from radio through infrared optical, ultraviolet, and X-ray.

I would first like to share with you a brief account of the picture of the universe that has emerged from these advances and then indicate the directions in which future research may go.

On a clear, dark night, the sky above us looks much as depicted on the first slide that I have brought. Each star that we see is a hot, gaseous sphere like our Sun. Like our Sun, in the deep interior of these stars, thermonuclear reactions go on producing light we see, and transforming hydrogen to helium in the interior of the stars to heavier elements.

With a large optical telescope, if you look carefully at that previous picture, you would have seen a bright band running across the sky, the Milky Way. We live in a system called a galaxy, and the Milky Way is the edge of that galaxy. With a large optical telescope, we see as many galaxies as stars, and in this slide we see a giant spiral galaxy similar to the system that we live in. At great distances, we see the galaxies cluster, like the stars cluster within individual galaxies. The next slide shows such a cluster.

Stars and galaxies are formed from clouds of gas and dust within the galaxies. The galaxies themselves are condensed from larger clouds of primordal gas. At great distances, we look back in time. This is due to the finite velocity of light. This look back into the past provides clues to the origin and evolution of our vast universe, so vast that the light we see left the most distant galaxies several billion years ago. If we apply our traditional technique of measuring velocity by use of the Doppler shift, we find that all of these galaxies are rushing away from us or, to be less parochial, from each other.

The more distant the galaxy, the larger its velocity of recession. This is the property characteristic of an expanding universe. Evidently then, at an earlier time, these galaxies were all much closer together. If we turn the clock back, that is reverse the velocities, the data suggest an early phase some 10 billion years ago when all matter and radiation were compressed into a dense, hot, primordal soup. The events that followed that high-density state are what astronomers call the Big Bang universe.

Many features of this dynamic world picture are still shrouded in mystery. There are many fascinating features which have been studied in detail. I have included in my written statement a figure describing some features of the early history of the Big Bang universe and have discussed it in somewhat more detail there than time here permits. I do, however, wish to highlight several features discussed there.

At a very early stage, hydrogen, helium, and deuterium were formed. That early stage was about one hour after the start of the Big Bang. The current abundance of deuterium or heavy hydrogen is a fossil remnant of this early stage, one of the ways we can see back that far.

About 1 million years after the Big Bang, matter became transparent to light, and light could then move freely across the universe. This first view of the primordal fireball is observed in the microwave region, and its discovery was a crucial argument in favor of the Big Bang scenario. Not until some 100 million years later did galaxies and stars begin to form from the initial hydrogen and helim clouds.

In the hot interiors of stars, thermal nuclear reactions go on producing the light we see from these stars. These thermal nuclear reactions transform some of the initial hydrogen and helium into heavy elements. Later generations of stars have condensed from this enriched gas, and on some planets, circling stars like our Sun, the carbon, oxygen, and nitrogen atoms through the womb of time have evolved into complex self-replicating life forms. So it is that the primordal hydrogen atoms arranged themselves in such forms as we so that they can ask from whence they came.

This is the story I wanted to tell because I believe it is a fair account of the arena in which modern astrophysics is set, and the opportunities to participate in this intellectual adventure are perhaps the best argument I can advance to you for a national program in astronomical research. I know, too, that astronomy captures the imagination of the layman, and some of the recent discoveries—quasars, pulsars, and black holes—are household words. Astronomy is also a close international community, in which U.S. astronomers play a leading role. Astronomy is too a technologically oriented effort, and the training and expertise that have developed have had their impact in many other areas.

Earlier I stated the current explosion in astronomical knowledge has resulted from our ability to span the entire electromagnetic spectrum, from radio waves to X-rays. The radiotelescope reveals a very different universe than does an optical telescope, while observations from space of X-rays shows us the high-energy phenomena. Only by putting together all this information do we get a comprehensive picture, and I would like to illustrate.

The cluster of galaxies that you saw earlier, viewed in the X-ray region, is shown on the next slide. This is the same cluster, and what we see is simply a hot intergalactic medium in which the galaxies are embedded.

If we look at bright radio galaxies in the radio region, we often see very large lobes, much larger than the star-filled disc of a galaxy.

The next slide shows a detail of the central part of these lobes. The galaxy itself is about one-third the size of this picture. The lobe itself extends out many times further than this. This is a picture that shows, however, the inner details of these trailing lobes and was obtained with the Very Large Array recently put into operation. The lobes are trailing because the galaxy that we know about from the optical region is moving through the intergalactic medium showed by the X-ray. We could not have put this picture together without——

Mr. Walgren. Excuse me, doctor. How far away is that?

Dr. CODE. This galaxy is 72 million parsecs, so that is 200 million light years. Light left it 200 million years ago.

This is just an illustration of how we could not know without putting things together like this. In formulating the program for the 1980's that Dr. Field will refer to, you will see that it is clear that an integrated program does indeed span the entire electromagnetic spectrum.

I will only make a couple of brief comments with respect to the NSF program, because I think it is responsive to the report and George Field will talk more about it. I think the thing that I had best say is on behalf of the American Astronomical Society, that the Astronomy Survey Committee report and the programs based on that NSF is formulating are the consensus of the astronomical community. Many society members—and the American Astronomical Society consists of about 3,800 members—participated in the development of that program.

Second, the American Astronomical Society is very pleased with the efforts of Dr. Knapp and the NSF staff to promote astronomical research and are pleased with the favorable reception of this decade report. Finally, the astronomical community recognizes the responsibility that these opportunities impose—namely, a responsibility to utilize these tools as effectively and efficiently as possible, and we accept that responsibility.

The society also has a committee on astronomy and public policy, and either through that committee or the officers, we stand ready to provide whatever assistance you may wish at a further time. Thank you.

[The prepared statement of Dr. Code follows:]

STATEMENT

OF

Dr. ARTHUR D. CODE

PRESIDENT, AMERICAN ASTRONOMICAL SOCIETY

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

MARCH 1, 1983

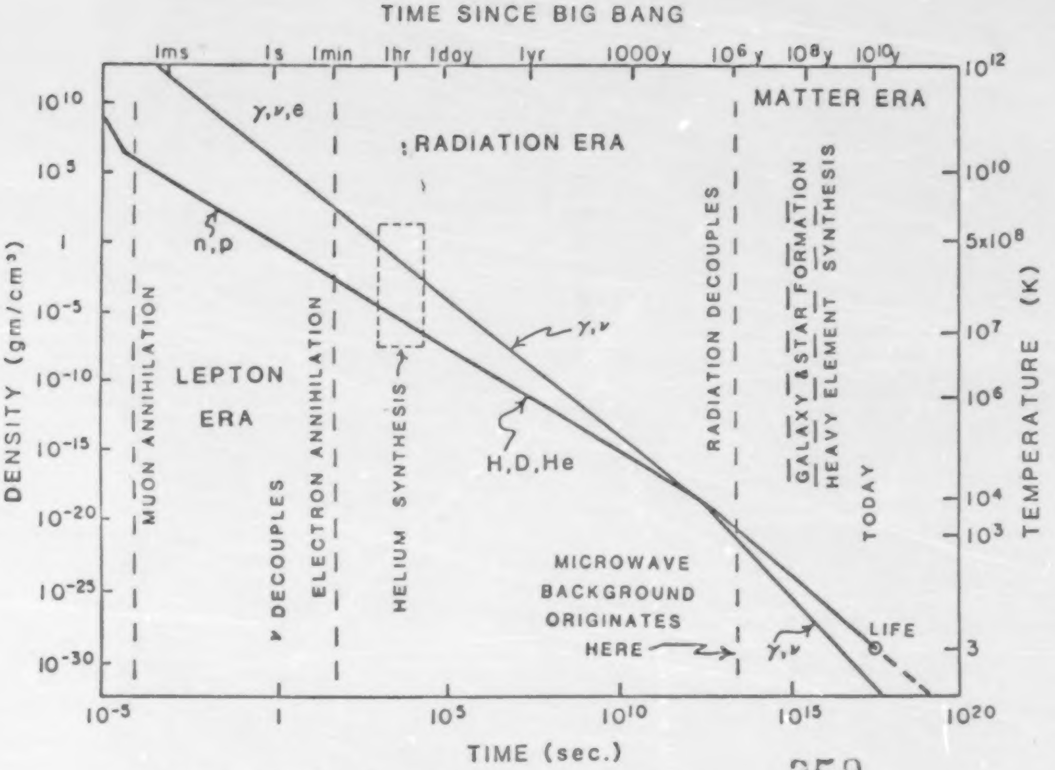
Mr. Chairman, members of the subcommittee:

My name is Arthur Code. I am a professor of Astronomy and Astrophysics at the University of Wisconsin. Currently I serve as president of the American Astronomical Society, the primary professional society of astronomers with a membership of approximately 3800 and it is in that role that I appear here today.

During the last two decades astronomy has witnessed an unprecedented growth of discovery and excitment of ideas, the roots of which lie in our ability to explore the entire electromagnetic spectrum from the radio region through the infrared, optical, ultraviolet and x-ray. One measure of this growth can be found in the ten-fold increase in the annual astronomical publication output over this time. In this same period the number of research astronomers has grown by a factor of five. In contrast to these figures research facilities, as measured by the increase in telescope collecting area, have expanded by only a factor of two and one-half, although technological advances have enabled astronomers to utilize these facilities more efficiently.

I would like to share with you a brief account of the picture of the universe that has emerged from these advances and then indicate the directions in which future research may take.

If we look up into the sky on a clear dark night, we see the multitude of stars shining as pinpoints of light. Astronomers have learned from the study of the light from these sources, however, their distances, sizes, masses, and chemical composition and have insight into their formation and evoluton. Each star we see is a hot gaseous sphere like our sun composed of hydrogen, helium and lesser amounts of all the other familiar chemical elements. A closer view would reveal clouds of gas from which clusters of stars are formed now and in the past. Many of these stars live out their lives burning nuclear fuel and returning gas to the interstellar medium. We live in a star system called a galaxy. If you look carefully you see a bright band, the Milky Way running across the sky. This is the edge of our spiral galaxy. A large optical telescope shows as many galaxies as stars. The larger of these galaxies contain some 100 billion stars, an equal amount of interstellar dust and gas and a tenuous extended envelope visible to radio telescopes. As we look beyond the local neighborhood of galaxies we see that galaxies cluster too. For galaxies themselves condensed out of larger clouds of primodial gas. At great distances we look back in time. This is due to the finite velocity of light, and this look back into the past provides clues to the origin and evolution of our vast universe. So vast that the light we see left the most distant galaxies several billion years ago. If we apply our traditional technique for measuring velocities by the use of the doppler shift, we find that all of these galaxies are rushing away from us or, to be less parochial, from each other. The more distant the galaxy, the larger is its velocity of recession, a property characteristic of an expanding universe. Evidently then, at an earlier time these galaxies were all much closer together. If we turn the clock back, that is reverse the velocities, the data suggests an early phase, some 10 billion years ago, when all matter and radiation were compressed into a dense hot primordial soup. The events that followed that high density state are what astronomers call the big bang universe. While many features of this dynamic world picture are still shrouded in mystery there are many fascinating features which have been studied in detail. The accompanying figure shows some of the features of the early history of the big bang universe.


TIME SINCE BIG BANG
Ims
Is
Imin
Ihr
Iday
Iyr
1000y
10^6 y
10^8 y
10^{10} y
10^{10}
10^5
1
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{-25}
10^{-30}
DENSITY (gm/cm³)
10^{12}
10^{10}
5×10^8
10^7
10^6
10^4
10^3
3
TEMPERATURE (K)
10^{-5}
1
10^5
10^{10}
10^{15}
10^{20}
TIME (sec.)
MATTER ERA
RADIATION ERA
LEPTON ERA
γ, ν, e
n, p
γ, ν
H, D, He
γ, ν
MUON ANNIHILATION
ν DECOUPLES
ELECTRON ANNIHILATION
HELIUM SYNTHESIS
RADIATION DECOUPLES
GALAXY & STAR FORMATION
HEAVY ELEMENT SYNTHESIS
TODAY
LIFE
MICROWAVE BACKGROUND ORIGINATES HERE

A few milliseconds after the commencement of the Big Bang, the temperature was about 100 billion degrees and the density some 10^{10} grams per cubic centimeter (a cubic centimeter would contain about 10 thousand tons of radiation and matter). As the universe expanded the density and temperature dropped so that today the average temperature is only 3° Kelvin while the spread out density of the universe corresponds to only one atom per cubic meter. About the very earliest stage of this picture high energy physics has much to say, for then the energies exceed those of the largest particle accelerators. Indeed the processes occurring in the Lepton era and the earlier Hadron era link the fundamental particles with gravitational forces and may have completely determined the subsequent structure of the universe.

Throughout the first million years, the density of radiation (gamma rays, and neutrinos) exceeded that of matter and thus is referred to as the radiation era. When the temperature fell to 500 million degrees neutrons, n became unstable, with a half life of the order ot 15 minutes. At the prevailing densities and temperatures, nuclear reactions set in converting the neutrons and protrons, p, into hydrogen (H), helium (He), and a trace of heavy hydrogen or deuterium (D). Well before any other elements could be formed the temperature and density dropped too low for further nuclear reactions. The present helium to hydrogen and deuterium to hydrogen ratio provides a direct observational link to this early stage in the thermal history of the universe.

Throughout most of the radiation era the photons are closely coupled to the matter being scattered back and forth between the electrons and ions. When the temperature had dropped to about 3000 K the matter became transparent to light and the light moved freely across the universe. In the absence of interaction with matter the photons retained a black body character while the temperature fell to its present 3^{0} K. Today we see this first view of the primordial fire ball in the microwave region of the spectrum. The discovery of the 3^{0} microwave background is generally regarded as the strongest argument for the standard big bang model.

Not until some 100 million years later, when matter dominated the universe did galaxies and stars begin to form. Density fluctuations in the intergalactic medium fragmented into massive clouds of hydrogen and helium. From these clouds clusters of galaxies condensed and within these galaxies further fragmentation resulted in the formation of stellar masses. These stars differed from our sun in at least two essential features. They were more massive and were composed of only hydrogen and helium with no traces of carbon, nitrogen, oxygen, iron and the other heavy elements present in he sun and here on earth. In the hot interior of stars, thermal nuclear reactions go on producing the light we see from these stars. These nuclear reactions transform some of the hydrogen and helium to heavier elements such as carbon and oxygen. In the final stages of a massive stars life instabilities set in which cause the star to explode as a supernova dispersing its mass back into the interstellar medium. In this way the interstellar gas becomes enriched with heavy elements. Later generations of stars have condensed from this enriched gas and so it is that the present abundance of the heavier chemical elements were formed in stars.

It is generally believed that in the formation of a single star like the sun, matter condenses and forms planets that orbit about the central star and that on those favorable planets organic molecules appear that are the building blocks of life. That these atoms should collect into complex amino acids and proteins that form living organisms in not nearly as unlikely as once thought. The dark molecular clouds observed by microwave telescopes are found to contain organic molecules not too different from these essential amino acids, while laboratory experiments have demonstrated how easy it is to manufacture amino acids from simple mixtures of gases expected to occur in primitive planetary atmospheres.

In the primeval oceans of the earth a brew of complex organic molecules formed and through the womb of time by the process of mutation and adaption self-organizing systems evolved. Thus the primordial hydrogen atoms by a series of complex but inevitable processes arranged themselves in such as we so they could ask from whence they came.

This is the story I wanted to tell because I believe it is a fair account of the arena in which modern astrophysics is set and the opportunities to partiipate in this intellectual adventure are perhaps the best arguments I can advance for a national program in astronomical research. I know too that astronomy captures the imagination of the layman and some of the recent discoveries -quasars, pulsars, and blackholes- are household words. Astronomy is a close international community in which U.S. astronomers play a leading role. In some areas, however, we have abrogated the initative, primarily due to budget constraints. Astronomy is a technologically oriented discipline and the training and expertise that are developed have had their impact in many other areas. Approximately 25% of those who have received a doctorate in astrophysics have moved into other areas and one-sixth now work in industry.

Earlier, I stated that the current explosion in astronomical knowledge has resulted from our ability to span the entire electromagnetic spectrum from the radio waves to X-rays. The radio telescope reveals a very different universe than does an optical telescope while observations from space of the X-rays shows us the high energy phenomena. Only by putting together all of this information do we get a comprehensive picture. For example, a cluster of galaxies when observed in the X-ray region shows a cloud of very hot diffuse gas in which the optical galaxies are immerse. In the radio region, radio bright galaxies often show large lobes of non-thermal gas much larger than the star filled main body. These radio lobes are due to the ejection at very high velocities of matter from the galactic nuclei. In a cluster these radio lobes are sometimes observed to trail behind due to the motion of the galaxy through the integalactic medium. Only by observations in all three spectral regions can these processes be understood.

In formulating the program for the 1980's the Astronomy Survey Committee constructed an integrated program encompassing those initatives that promised most to answer the many new challenging questions that face us. As you see from that report, the initatives span the electromagnetic spectrum and are each complementary and necessary to meet this challenge. The VLBA will carry out research that no other instrument can explore. The spatial resolution will far surpass anything currently available and promises answers to many of the puzzling questions relating to energetic events in the nuclei of galaxies.

The New Technology Telescope (NTT), which is now on the drawing boards, is vital if we are to fully interpret the new results we expect Space Telescope and later the large X-ray facility, AXAF, to provide. Finally we must never forget that the data does not represent new knowledge unless we adequately equip our universities and observatories with the computing and analyzing power to digest them, nor shall we be prepared to capitalize on new discoveries if we do not provide adequate development support for next generation instrumentation, and the training of future scientists.

Let me conclude by making a few comments on behalf of the American Astronomical Society. First I should remark that the Astronomy Survey Committee Report "Astronomy and Astrophysics for the 1980's" represents the concensus of the Astronomical community, many society members participated in its development and all had an opportunity to review it.

Secondly, the AAS is very pleased with the efforts that Dr. Knapp and the NSF staff have made to promote astronomical research and pleased, too, at the favorable reception the decade report has received. The astronomical community recognizes the responsibilities that these opportunities impose. Namely, the responsibility to utilize these tools as effectively and efficiently as possible and we accept that responsiblity.

Finally the American Astronomical Society has a Committee on Astronomy and Public Policy and either through that committee or the officers of the society we stand ready to provide whatever assistance you may wish at a future time. Thank you.

Mr. WALGREN. Dr. Field.

[The biographical sketch of Dr. Field follows:]

BIOGRAPHICAL SKETCH OF DR. GEORGE FIELD

George Field is a theoretical astrophysicist trained at MIT and Princeton. His interests are in the dynamics of gas in interstellar and intergalactic space, and in the origin of magnetic fields in stars. He has taught at Princeton, Caltech, Berkeley, and Harvard, and from 1973 to 1982 served as director of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. He is presently on the staff of the Smithsonian Astrophysical Observatory and a professor at Harvard.

From 1978 to 1982 he served as chair of the Astronomy Survey Committee, a group of 21 scientists appointed by the National Academy of sciences to survey the needs of astronomy and astrophysics and to develop priorities for a comprehensive program for the 1980's. The Astronomy Survey Committee report was published in June, 1982, under the title "Astronomy and Astrophysics for the 1980's"; it is available from the National Academy Press.

STATEMENT OF DR. GEORGE FIELD, CHAIRMAN, ASTRONOMY SURVEY COMMITTEE NATIONAL ACADEMY OF SCIENCES

Dr. FIELD. In the interest of time, Mr. Chairman, I will abbreviate my prepared remarks.

Dr. Code referred to the fact that there are advanced instruments that are required to make frontier astronomical observations. Over the years, the astonomers of the United States have recognized their responsibility to prioritize the construction of such instruments. There have been three National Academy Astronomy Survey Committees that have done that: 1964, 1972, and 1982. The latest one, which I chaired, was published in 1982. In a separate but related activity, I chaired a National Academy Research Briefing Panel on Astronomy and Astrophysics for Dr. George Keyworth, and you should have before you the report of the Briefing Panel, as well as a written summary of my remarks. The Briefing Panel report is consistent with the Astronomy Survey Committee Report, and addresses itself specifically to the fiscal year 1984 budget.

The implications for NSF of the Astronomy Survey Committee are indicated on page 17 of the Briefing Panel report. The total cost of new programs for the 10-year period of the 1980's, is estimated to be approximately $1.9 billion in 1980 dollars. That figure may be compared with a figure of $1.7 billion in the same units, recommended by the Greenstein Committee in 1972. In fact, most of the recommendations of the Greenstein Committee were in fact implemented, and therefore we believe that our recommendations are responsible within that fiscal framework.

Two of the major new programs that we recommend are under the purview of the NSF and, therefore, of this subcommittee. One is the VLBA, of which you have heard earlier; the other is the New Technology Telescope [NTT] for optical and infrared wavelengths, of which you also heard something. Their total cost is estimated at $150 million in our report. This figure substantially exceeds that of the Very Large Array, which was funded by the National Science Foundation during the 1970's. Moreover, the committee recommended a substantial investment in what we called prerequisites for new research initiatives, which included instrumentation, detectors, theory, laboratory astrophysics, and other supporting activities.

All told, the committee concluded that an increase of about 30 percent in the NSF astronomy division's operations budget will be required, and also—and this should be borne in mind by the subcommittee—that funds needed by NSF for major construction will also be substantially higher than in the 1970's.

As to fiscal year 1984, the Research Briefing Panel recommended a number of programs be selected for emphasis in 1984, and among them two major new programs, the VLBA and the NTT fall into the purview of this committee. They also recommended that of the five prerequisites for new research initiatives, three be selected for emphasis in fiscal year 1984.

Let me comment now on the President's fiscal year 1984 budget. By increasing the funding for astronomical sciences at NSF by $16 million, the President's fiscal year 1984 budget will make possible substantial progress in each of the areas recommended by the Research Briefing Panel to Dr. Keyworth. Specific emphasis is placed upon the development of astronomical instruments, data analysis, theory, and computational facilities.

The NSF plans to implement design studies on the VLBA. I strongly endorse this action as responsive to the Briefing Panel report. It is also anticipated there will be sufficient funds available to continue development on the NTT. This action was also recommended by the Briefing Panel. Also, it is planned to accelerate the development of a 10-meter submillimeter wave telescope, which is a small program given highest priority by the Astronomy Survey Committee. It was also recommended for accelerated development by the Research Briefing Panel.

In conclusion, I would say that the President's 1984 budget is highly responsive to those recommendations which concern NSF, in both the Astronomy Survey Committee Report and in the Briefing Panel report. I would also like to say that I applaud the administration for its general recognition of the need to strengthen the scientific capability of the Nation.

Finally, I would be remiss, Mr. Chairman, if I did not point out to the subcommittee that the 1984 budget is but the first step in implementing the Astronomy Survey Committee recommendations for NSF. The substantial increases requested for NSF on the 1984 budget enable design studies on the VLBA and the NTT, and a major step toward the needed increase in operating funds which I have discussed previously. But there will need to be substantial increases, starting in fiscal year 1985, in order to proceed with the orderly construction of the VLBA and the NTT. Thank you.

Mr. WALGREN. It is your conclusion that they are highly responsive. Are there particular programs where you feel they are being unresponsive to the committee reports?

Dr. FIELD. In all candor, no. They have been extremely responsive. I think our concern is for the future. We realize that these programs will be expensive when we get into the construction phase, and it is most important for the Congress to recognize that fact and to take steps to assure that the construction funds do not impact the operating expenses which are already necessary to carry on the continuing program.

Dr. CODE. May I interject?

Dr. Field was answering your question with respect to just the NSF budget. There are areas of the NASA funding that astronomers are a little uncomfortable about.

Mr. WALGREN. Could we detail them just a little bit? The overall Science and Technology Committee does look at NASA.

Dr. FIELD. One of our concerns, as I mentioned, were what we call the prerequisites for new research initiatives. These are the on-going activities that make possible advances in technology and new instrumentation at universities. NSF responded very strongly in that area by increasing project support by 32 percent in 1984. My understanding is that the NASA budget does not respond as firmly to that initiative, even though we recommended that NASA make an effort comparable to that of NSF.

If I may, Mr. Chairman, there is also a concern about a specific experiment that we discussed in the Astronomy Survey Committee Report, relating to neutrinos from the Sun. It is a long-standing problem in astrophysics, that although we can calculate from basic physics the number of neutrinos that should be reaching us from the Sun as a consequence of the nuclear reactions there, the measurements carried out over a long time at Brookhaven National Laboratory give a number only one-third of this theoretical expectation. This contradiction throws into doubt our whole understanding of the Sun and stars.

There is a way to resolve this experimentally, called the gallium solar neutrino experiment. This would cost something like $1 million per year over a long period of time, and apparently the Department of Energy is willing to pay that cost, but a substantial capital expenditure is also necessary to purchase 50 tons of gallium. This is a material which is sensitive to the neutrinos in question and which can be analyzed to give a decisive answer. We were hoping that in the 1984 budget, the DOE would provide for that capital expenditure, but apparently they have chosen not to do so. So that is a problem that should be addressed somehow, and it is possible that NSF could play a role in that.

[The prepared statement of Dr. Field follows:]

March 1, 1983

Testimony on Astronomy and Astrophysics

by George Field*

before the

Subcommittee on the National Science Foundation

of the

House Committee on Science and Technology

Honorable Doug Walgren, Chairman

Recent Discoveries in Astronomy

Astronomy is now in an age of discovery unparalleled since the invention of the telescope. Stars only 10,000 years old have been discovered hiding in interstellar clouds; they must have been born just yesterday in the 10-billion year lifetime of our Galaxy. Dying stars have also been found: neutron stars formed when stars as big as the sun collapsed to a size smaller than Manhattan. Two stellar black holes, believed to be smaller than a pinhead, have been found orbiting normal stars. Evidence has been found that there is a black hole with a mass a million times that of the sun lurking at the center of the Milky Way galaxy. Other galaxies seem to have even more massive black holes - up to a billion suns - in their centers. Some of these galaxies are emitting stupendous amounts of energy in narrow jets which may be the result of the gravitational energy released when gas falls into massive black holes. Astonishingly, blobs within these jets have been observed to move at speeds up to 10 times that of light: this phenomenon has still not been completely explained.

The universe itself is the result of a giant explosion we call the Big Bang, which occurred about 10 billion years ago. There is evidence that the matter we now see around us is the remnant of a much denser mixture of matter and antimatter, most of which annihilated when the universe was only 1/10,000 of a second old. The details of what happened at such incredibly early times are now under investigation using unified theories of elementary particles, some of which suggest that much of the unseen matter believed to exist in the universe is in the form of exotic particles like gravitinos. A steady stream of discoveries has brought us to the threshold of the greatest mystery of all: how the universe came into being.

Astronomy and Astrophysics in the United States

Modern astronomy develops hand in hand with physics. Innovative instruments for studying the universe have come out of physics laboratories, and our entire interpretation of astronomical phenomena is based upon the laws of nature developed by physicists.

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* Biographical sketch in Attachment 1.

Even before World War II the United States had a strong tradition in astronomy, particularly with the large optical telescopes in the West. Since World War II, techniques have been developed to detect and study objects at other wavelengths as well. A variety of radio telescopes were built, culminating in the Very Large Array in New Mexico, funded by NSF and completed in 1980. NASA has orbited a variety of instruments to study radiation which does not penetrate the atmosphere, including the *Einstein* X-Ray Observatory and the International Ultraviolet Explorer in 1978, and the Infrared Astronomical Satellite in 1982; a large optical-ultraviolet Space Telescope is scheduled for launch in 1985. NSF has also supported the construction of a number of ground-based optical-infrared telescopes, including 4-meter telescopes on Kitt Peak in Arizona and Cerro Tololo in Chile. Through such continued investments in instruments, the United States has established preeminence in astronomical research.

Decade Reviews: Priorities for Astronomy

Astronomical facilities based upon the most advanced technology are often expensive. Mindful of this, the U.S. astronomical community long ago realized that it would be necessary to establish priorities for constructing such facilities. Over the years, the National Academy of Sciences has sponsored three Astronomy Surveys for this purpose, in 1964, 1972, and 1982. The Report of the latest Astronomy Survey Committee, which I chaired, was published in June of 1982, and is available from the National Academy Press. Entitled *Astronomy and Astrophysics for the 1980's*, this Report surveys the needs of astronomy and astrophysics, and develops priorities for a comprehensive program for the 1980's. My remarks today are based upon that Report.

In a separate but related activity, I also chaired a Research Briefing Panel on Astronomy and Astrophysics, set up by the Academy in late 1982 to brief Presidential Science Advisor Dr. George Keyworth on the current status of the field, particularly those areas deemed likely to return the highest scientific dividends as a result of incremental federal investments in FY 1984. The Report of the Briefing Panel, Attachment 2 to this statement, is based upon the Astronomy Survey Committee Report, is entirely consistent with that report, and is given in the same format. A summary of the recommendations of the Astronomy Survey Committee is given in Appendix B of the Research Briefing Panel Report; a concise table, including estimated costs, appears on page 17.

Implications for NSF

As indicated on page 17, the total cost of new programs for the decade of the 1980's is estimated to be about 1.9 billion in 1980 dollars; this figure may be compared with the 1.7 billion in 1980 dollars recommended for the 1970's by the Greenstein Committee in 1972. Most of the recommendations of that Committee were in fact implemented.

Two of the major new programs, the Very Long Baseline Array (VLBA) of radio telescopes, and the New Technology Telescope (NNT) for optical and infrared, fall under the purview of NSF. Their total estimated cost, $150 million, substantially exceeds that of the VLA, (about 100 million in 1980 dollars) funded by NSF in the 1970's. Moreover, the Committee recommended a substantial investment (about $190 million) in Prerequisites for New Research Initiatives, including instrumentation and detection; theory and data analysis, computational facilities, laboratory astrophysics, and technical support at ground-based observatories; it is anticipated that about half of this would come from NSF.

All told, the Committee concluded (p.18) that "...an increase of about 30 percent in the [NSF] Astronomy Division's operations budget ....will be required", that "funds needed by NSF for major construction ... will also be substantially higher", and that "these increases in the NSF budget for ground-based astronomy are essential to maintain an effective partnership with space astronomy during the 1980's."

The Research Briefing Panel recommended (pp. 2-4) that a number of the programs prepared by the Astronomy Survey Committee be selected for emphasis in FY 1984. Among these recommendations, two major new programs, the Very Long Baseline Array (VLBA) of radio telescopes, and the New Technology Telescope (NNT) of the 15-meter class for optical and infrared, fall into the purview of NSF as indicated above. The Panel also recommended that of the five Prerequisites for New Research Institutions in the Astronomy Survey Report, three (Instrumentation and Detectors, Theory and Data Analysis, and Computational Facilities) be selected for emphasis in FY 1984, with the anticipation that the funding for these Prerequisites would be shared by NSF and NASA.

FY 1984

By increasing the funding for Astronomical Sciences at NSF by $16.3 million, the President's FY 1984 Budget will make possible substantial progress in each of these programs. Specific emphasis is placed upon the development of astronomical instruments, theory and data analysis, and computational facilities, both at the national astronomy centers and at universities. In view of NSF Director Dr. Edward Knapp's recognition of "the need to revitalize the research base in our nation's universities and colleges," I am pleased to note an increase of 32% planned for Astronomy Project Support.

The NSF plans to implement design studies on the VLBA. I strongly endorse this action as responsive to the Briefing Panel Report. It is anticipated that there will be sufficient funds available to continue technology development efforts on the NNT; this action was also recommended by the Briefing Panel. Finally, it is planned to accelerate the development of a 10-meter submillimeter-wave telescope. This project, the small new program given highest priority by the Astronomy Survey Committee, was also recommended for accelerated development by the Research Briefing Panel (p. 5).

I conclude that the President's 1984 Budget is highly responsive to those recommendations concerning NSF in both the Astronomy Survey Report and the Briefing Panel Report. I also applaud the Administration for its recognition of the need to strengthen the scientific capability of the nation in all fields by allocating allocating precious resources to that end.

I would be remiss, Mr. Chairman, if I did not also point out that the 1984 budget is but the first step in implementing the Astronomy Survey Committee recommendations for NSF. The substantial increases requested for NSF in the FY 1984 budget enable design studies on the VLBA and the NTT, and a major step toward the needed increase in operating funds discussed above, but there will need to be substantial increases starting in FY 1985 in order to proceed with the orderly construction of the VLBA and the NTT.

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Report of the Research Briefing Panel on Astronomy and Astrophysics

Committee on Science, Engineering,
and Public Policy
National Academy of Sciences
National Academy of Engineering
Institute of Medicine

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The Committee on Science, Engineering, and Public Policy is a joint committee of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. It includes members of the councils of all three bodies.

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PREFACE

This is one of seven research briefings prepared in response to a request from Dr. George A. Keyworth, Science Advisor to the President and Director of the White House Office of Science and Technology Policy (OSTP). The effort was directed by the Committee on Science, Engineering, and Public Policy (COSEPUP), a joint committee of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

Topics for the seven research briefings were selected by OSTP. For each topic a balanced panel of 11-13 experts was organized to develop the briefing. The specific charge to each panel was to critically assess its field and to identify those research areas within the field that were likely to return the highest scientific dividends as a result of incremental federal investments in FY 1984. It was also emphasized that these briefings were not to be construed as substitutes for the much more detailed surveys occasionally undertaken in major scientific fields (e.g., the recent report of the National Research Council's Astronomy Survey Committee entitled Astronomy and Astrophysics for the 1980's, Volume 1).

Through discussions with OSTP, the seven topics were defined as follows:

1. MATHEMATICS: Research covering the following fields of investigation: statistics, pure and applied mathematics, mathematical systems theory, numerical analysis, operations research, computational mathematics, and scientific computing.

2. ATMOSPHERIC SCIENCES: The study of the physical, chemical, and dynamic properties of the atmosphere and its interactions with the Earth, the oceans, and the planetary environment with a view to understanding and predicting the atmosphere's changes and behavior as manifested in weather, climate, air quality, and other characteristics relevant to human society, both as a result of natural processes and as influenced by human activities.

3. ASTRONOMY AND ASTROPHYSICS: Research with the objective to obtain information about astronomical bodies by remote sensing from the surface of the Earth, from the Earth's atmosphere, and from Earth orbit.

4. AGRICULTURAL RESEARCH: Research of greatest promise for increasing the productivity and efficiency of American agriculture, including:

- plant sciences targeted on developing more productive, resistant, tolerant, and energy-efficient crop plants;
- an objective assessment of the realistic expectations of genetic engineering for developing more productive, resistant, tolerant, and energy-efficient crop plants; and
- research on crops and cropping practices that are more resource conservative.

5. NEUROSCIENCE: Research directed toward understanding the molecular, cellular, and intercellular processes in the central nervous system (CNS) and the way in which those processes are integrated in CNS functional control systems, with emphasis on research relating CNS functions with behavior.

6. HUMAN HEALTH EFFECTS OF HAZARDOUS CHEMICAL EXPOSURES: Research on the responses of organisms to hazardous chemical exposures, including:

- the nature of the steps leading to damage to the organisms;
- the mechanisms and kinetics of metabolism of hazardous substances;
- the nature of protective responses and repair mechanisms; and
- the in vitro, animal bioassay, and epidemiological methods used to characterize hazardous exposures.

7. MATERIALS SCIENCE: Research concerned with reaching a clearer understanding of the complex relationships that exist among the atomistic structure, composition, and defects of materials and their behavior in an engineering environment. Specific areas of investigation include those concerned with surface characterizations, defect structure, electronic structure, catalysis, the theory of crystalline solids, and the properties of solids (e.g., electrical, magnetic, optical, thermal, and mechanical).

Each panel met once, for 2 or 3 days, to carry out its charge. Knowledgeable representatives of government and the private sector were invited to provide input to the panels. Rapporteurs, knowledgeable in the field, were present to summarize the discussions and prepare initial drafts of briefing papers. These papers were reviewed and revised by the panel members and served as the bases for the oral briefings presented to federal officials.

The seven one-hour briefings, presented by panel chairmen and, in some cases, 1 or 2 other panel members, were reviewed by COSEPUP in mid-October and presented to Dr. Keyworth and members of his staff between October 26 and November 18, 1982. The same briefings were subsequently presented to Dr. Edward Knapp, Director of the National Science Foundation, and other Foundation officials on three days in December. Briefings for other interested departments and agencies were held separately on the same dates.

None of this would have been possible without the financial support of the National Science Foundation and the cooperation, under difficult time constraints, of the panel members and staffs. We are indebted to both groups.

If judged useful to federal decision makers, the seven initial research briefings developed as an experiment in 1982 could serve as the basis for research briefings on other major fields of science in future years. Such briefings could supplement other inputs and become important new channels for communication between the federal government and the scientific community.

George M. Low, Chairman
Committee on Science, Engineering, and
Public Policy

REPORT OF THE RESEARCH BRIEFING PANEL ON ASTRONOMY AND ASTROPHYSICS

I. ASTRONOMY AND ASTROPHYSICS FOR THE 1980's

We live in an extraordinary age for astronomy, unmatched since the time of Galileo. The discoveries of the past 20 years, made from both ground-based and space observatories have radically changed our understanding of the Universe. Quasars, x-ray sources, pulsars, polyatomic molecules in interstellar space, and the cosmic microwave background radiation were discovered in the 1960's. The 1970's added discoveries of accretion of matter by neutron stars, observational evidence for a stellar black hole, intergalactic gas at 100 million degrees, apparent expansion at greater than the speed of light in quasars, volcanic activity on Io, the origin of high-velocity solar-wind streams in "holes" in the solar corona, rings around Uranus and Jupiter, observational evidence for gravitational radiation from a binary star, gamma-ray bursts, and the gravitational refraction of light from quasars by intervening galaxies.

Through federal support, U.S. astronomers have remained at the forefront of astronomy and astrophysics during this period, maintaining a position of world leadership established early in this century. Spectacular advances in x-ray, gamma-ray, infrared, and ultraviolet astronomy--supplementing the more established techniques of optical and radio astronomy--have opened virtually the entire electromagnetic spectrum to cosmic observations. The U.S. scientific community stands ready to exploit this opportunity with present and planned facilities of unparalleled power and scientific promise.

Special "decade reviews" carried out by the National Academy of Sciences (NAS) have periodically surveyed the status of the field and have advanced recommendations for future research programs. The first two such surveys, completed in 1964 and 1972, had a powerful impact on the conduct of U.S. research during the period 1960-1980. The recommendations of the third such decade review are contained in the recent report of the Astronomy Survey Committee, Astronomy and Astrophysics for the 1980's (National Academy Press), Washington, D.C., 1982; see Appendix A). Timely response to these recommendations will permit U.S. scientists to maintain leadership in the most promising areas of astronomy and astrophysics during the 1980's.

The Astronomy Survey Committee report took three years to complete and engaged over 130 scientists. Its final recommendations were highly selective: of many dozens of projects considered, only a small number were recommended for new funding for the 1980's (see Appendix B for a summary taken from the 1982 report). The National Academy of Sciences has accepted these recommendations as the consensus of the U.S. astronomical community, and they have also received the official endorsement of the American Astronomical Society.

The present Briefing Panel has based its recommendations for FY 1984 entirely on the recently completed Survey Committee report, and they follow the same format as does the report. The Survey Committee first stressed the importance of Approved, Continuing, and Previously Recommended Programs for progress in research during the 1980's. The Committee next emphasized that Prerequisites for New Research Initiatives are essential to the success of present and planned major research facilities. Finally, the Committee recommended the funding of New Programs for the 1980's in three categories: Major, Moderate, and Small. Throughout its study, the Survey Committee strove to be fiscally realistic: the overall program recommended for the 1980's is roughly comparable in scale with that actually carried out during the 1970's on the basis of the recommendations of the previous decade review.

From the projects recommended for the 1980's in the Survey Committee report, the Briefing Panel has selected for recommendation here only those that are particularly timely for FY 1984 budget action. (It is important to recall again that the programs recommended by the Survey Committee themselves reflected a careful selection from a great many proposals made to that Committee.) Favorable action by the government in FY 1984 on the programs recommended here will constitute an important step toward ensuring the vitality of U.S. astronomical research in the decade ahead. The Panel calls particular attention to the need for FY 1984 commitments to begin two important projects: the Shuttle Infrared Telescope Facility (SIRTF) within the NASA Spacelab program and a Very Long Baseline Array (VLBA) of radio telescopes within the program of the NSF Astronomy Division.

II. THE RECOMMENDATIONS

The recommendations of the Briefing Panel for FY 1984 are summarized in this section in the same format as in the Survey Committee report. They are discussed in more detail in Section III.

Approved, Continuing, and Previously Recommended Programs

Shuttle Infrared Telescope Facility (SIRTF). This major Spacelab facility is the only space-astronomy project in this category that has not yet been started. SIRTF will achieve thousandfold gains over present telescopes in the important thermal-infrared region of the spectrum. The Panel recommends that NASA re-establish its original strong commitment to a vigorous Spacelab program by immediately implementing SIRTF through a Phase B study, which will require an augmentation to the Spacelab program of $2 million in FY 1984 and $2.5 million in FY 1985.

Prerequisites for New Research Initiatives

Instrumentation and Detectors, Theory and Data Analysis, and Computational Facilities. The Survey Committee identified five Prerequisites which are essential to the success of major research programs but which are inexpensive by comparison. The Panel has selected the three Prerequisites stated above because funding them will immediately increase the efficiency with which observations are made and analyzed and the degree to which the resulting data can be understood on the basis of physical laws. The Panel recommends that an augmentation of $10 million/year above present funding levels, to be shared by NSF and NASA, be made available for these Prerequisites beginning in FY 1984.

NEW PROGRAMS

Major New Programs

Advanced X-Ray Astrophysics Facility (AXAF)

This facility, which was accorded the highest priority among all major new programs by the Survey Committee, will be the nation's first permanent x-ray observatory in space. The Panel recommends augmentation of Phase B design studies by $2.5 million in FY 1984 and by $5 million in FY 1985 in order to ensure a new start for AXAF in FY 1986.

Very Long Baseline Array (VLBA) of Radio Telescopes

This ground-based facility, which was accorded the highest priority among major new ground-based programs by the Survey Committee (and second highest priority among all major new programs), will permit radio astronomers to map detail in cosmic radio sources with an angular resolution of 0.2 milliarcsecond. The Panel recommends that, in FY 1984, NSF commit to the construction of the VLBA and ensure its timely completion by making available $2-3 million for a final design study in FY 1984. Construction will require additional funding of $60 million spread over FY 1985-1987.

New Technology Telescope (NTT) of the 15-Meter Class

A ground-based NTT, which was accorded third highest priority among all major new programs by the Survey Committee, will make unique contributions to optical and infrared astronomy, particularly through optical and infrared spectroscopy of faint stars and galaxies and through high angular resolution studies in the infrared. The Panel recommends that design studies for the NTT, which were considered to be of the highest priority by the Survey Committee, be augmented to the level of $2 million in FY 1984 and in FY 1985 so that a final design for NTT can be selected by FY 1986.

Moderate New Program

Augmentation to the NASA Explorer Program

The Explorer program remains a flexible and highly cost-effective means to pursue new opportunities in space astronomy in nearly every part of the electromagnetic spectrum. The Survey Committee recommended an immediate and substantial augmentation to the Explorer budget in order to restore it to the healthy level of effort of 1970, which prevailed before the ravages of inflation. The Panel recommends that the Explorer budget be augmented by $20 million/year beginning in FY 1984 in order to accelerate the development and launch of three Explorer missions now in various stages of preparation: the Cosmic Background Explorer (COBE), the Extreme Ultraviolet Explorer (EUVE), and the X-Ray Timing Explorer (XTE).

III. JUSTIFICATION FOR THE RECOMMENDATIONS

Approved, Continuing, and Previously Recommended Programs

Shuttle Infrared Telescope Facility (SIRTF)

The programs recommended in the Astronomy Survey Committee's report were selected from research activities that were, at the beginning of the survey, candidates for implementation in FY 1983 and beyond. However, the Committee also emphasized "the importance of approved, continuing, and previously recommended programs to the progress of astronomical research during the remainder of the decade. The present Committee's recommendations take explicit account of such programs and build upon them" (Chapter 2, page 13; see also Appendix B of this Briefing Panel report). The Panel notes that SIRTF is the only space-astronomy project in this category that has not yet been implemented. The Survey Committee went on to say (Chapter 4, page 112--see also Appendix C to this Briefing Panel report), "The proposed SIRTF will be the cornerstone of research in infrared astronomy during the 1980's. The Astronomy Survey Committee joins with the Space Science Board's Committee on Space Astronomy and Astrophysics . . . in recommending this facility as the first major infrared telescope in space." The Panel enthusiastically supports this recommendation.

In support of its recommendation for SIRTF, the Survey Committee wrote: "SIRTF will permit investigations over the enormous range of wavelengths from 2 to 300 μm. For some important types of observations it will, because of its cryogenically cooled optics, yield a sensitivity gain of 1000 over the largest existing ground-based and airborne infrared telescopes; this gain in sensitivity is so large that it is not unreasonable to expect that SIRTF will make important and unexpected discoveries."

SIRTF will make it possible to observe the highly red-shifted light originating far in the past from very distant galaxies, so that we may study their early evolution. It will be able to detect very low-mass stars in nearby galaxies, which may account for the hidden mass in those galaxies, and to penetrate the obscuring dust of the dense cores of molecular clouds to study the process of star formation. SIRTF will also be able to investigate the thermal energy balance of the more distant planets and to greatly improve our knowledge of their atmospheric compositions.

Because of its wavelength range and sensitivity, SIRTF will in addition permit detailed spectroscopic studies of the infrared sources which will be discovered by the IRAS infrared survey satellite due to be launched in the very near future. Just as the 200-inch Hale telescope is used to investigate the stars and galaxies discovered by the 48-inch Schmidt telescope on Mt. Palomar, SIRTF will investigate new infrared sources discovered by IRAS.

A reaffirmation of NASA's original strong commitment to Space Shuttle research beginning in FY 1984 will be necessary to permit the timely development of SIRTF within the Spacelab program. With the flight of IRAS the development of cryogenically cooled optical systems for infrared space observations will have been completed and tested in space, thus removing a major barrier to the rapid development of SIRTF, a much more powerful and sensitive facility.

Prerequisites for New Research Initiatives

The Astronomy Survey Committee called attention to five Prerequisites for New Research Initiatives and recommended augmentations in each: "These Prerequisites are essential for the success of major research programs but are inexpensive by comparison." The Briefing Panel recommends that three of the Prerequisites receive augmentations in FY 1984.

Instrumentation and Detectors

Great strides in the development of new instruments and detectors were made during the 1970's, permitting enormous increases in observing efficiency, but so far only a handful of the telescopes at major observatories have been equipped with state-of-the-art instruments and detectors. Moreover, new generations of instruments and detectors must be developed in concert with the design and operation of future ground-based and space observatories. The application of state-of-the-art technology will greatly amplify the quantity and quality of the data obtained, at a small fraction of the cost of the major facilities that will use these instruments and detectors. Augmented funding for instrumentation will also permit accelerated development of a 10-meter submillimeter-wave radio antenna--the Astronomy Survey Committee's highest-priority recommendation for small new programs--by the NSF.

Theory and Data Analysis

The aim of astronomy is an understanding of the Universe, not simply the gathering of observational data. Vigorous programs of data analysis and complementary theoretical investigations are essential to achieve this aim, but both have been underfunded in the past. In particular, NASA has not adequately supported the theoretical analysis of data from space astronomy missions. Moreover, theoretical understanding of recent discoveries is important for optimizing the designs of future instruments. Increased support by NASA and NSF for theory and data analysis will greatly enhance the scientific return from both ground-based and space-astronomy facilities.

Computational Facilities

Modern instrumentation and detectors are highly dependent upon computers for control, data readout, and on-line processing. Because of the complexity of astronomical systems such as exploding stars and galaxies, theoretical investigations and data analysis cannot be carried out by purely analytic methods, and are therefore also dependent upon numerical calculations. The steady and rapid decrease in the cost of computing power opens up vast new opportunities for scientific advance. An augmentation to NSF and NASA funding of computational facilities will be a major step in achieving maximum effectiveness of new instruments and data-analysis programs.

NEW PROGRAMS

Major New Programs

Advanced X-Ray Astrophysics Facility (AXAF)

The United States pioneered world leadership in x-ray astronomy, beginning with the 1962 discovery of extrasolar x-ray sources by means of a brief rocket flight, through the first all-sky survey of x-ray sources carried out by the UHURU satellite in 1970, to the flight of High Energy Astronomical Observatory (HEAO) satellites during the period 1977-1981. As a result, x-ray observations have now attained an importance in contemporary astronomy comparable to those in other wavelength regions. In FY 1986, following completion of Phase B studies, NASA should begin construction of the Advanced X-Ray Astrophysics Facility (AXAF), the nation's first permanent x-ray observatory in space. The Astronomy Survey Committee accorded this project highest priority of all major new programs for the 1980's.

With up to 100 times greater sensitivity than any previous x-ray mission, AXAF will provide U.S. astronomers with a powerful and long-lived new capability. Working in concert with the Very Large Array and the VLBA in the radio region, and with Space Telescope in the visible and ultraviolet spectral regions, AXAF will be an important part of an ensemble of major U.S. facilities covering much of the electromagnetic spectrum and capable of observing objects simultaneously at different wavelengths; this capability will greatly increase the scientific value of the data obtained.

AXAF will be used to study faint x-ray sources in the farthest reaches of our Galaxy as well as individual high-luminosity sources in hundreds of other galaxies. High-resolution imaging, together with spectroscopic and polarimetric observations, will reveal the composition and dynamics of supernova remnants, galactic halos, and clusters of galaxies. Observations of remote galaxies and quasars will probe the effects of evolution in the early Universe.

Augmentations of funding for final AXAF design studies in each of FY 1984 and FY 1985 are necessary for the timely completion of Phase B studies.

Very Long Baseline Array (VLBA) of Radio Telescopes

The United States has led the world in the development of Very Long Baseline Interferometry (VLBI), a technique that permits the combination in a central computer of radio-frequency observations from widely separated observing sites to produce images of cosmic objects with extraordinary angular resolution. The Very Long Baseline Array (VLBA) will include about 10 antennas, placed in Alaska and Hawaii as well as across the continental United States. This facility will map cosmic radio sources of very small angular size with a fineness of detail equal to that which could be achieved by a single radio dish as large as an entire continent. The angular resolution achieved--0.2 milliarcsecond--is equivalent to being able to read, from Los Angeles, a Post headline in Washington, D.C. Among many applications of profound importance, this instrument will probe the small-scale structure surrounding the enigmatic energy sources in the cores of quasars and active galactic nuclei and will directly determine the distance scale within our Galaxy with unprecedented accuracy (see Appendix D).

The National Science Foundation is currently completing a peer review of the VLBA, on the basis of which the Panel feels that NSF should be in a position to make a positive commitment to this important program. Accordingly, the Panel recommends that in FY 1984 NSF commit to construction of the VLBA and ensure its timely completion through award of $2-3 million for a final design study in FY 1984. The Array utilizes proven technology, and its costs may be accurately estimated. Construction of the VLBA will require additional funding of $60 million spread over FY 1985-1987. However, it will be critically important for NSF to construct and operate the VLBA without a further erosion of programmatic base funds within the NSF Astronomy Division.

Approval of the VLBA will mark the end of a long hiatus in the construction of new ground-based astronomical facilities by NSF. The 1970's saw the completion of the Very Large Array radio telescope near Socorro, N.M., but construction of a 25-meter millimeter-wave radio telescope--also recommended by the 1972 decade review committee--was deferred for a number of years for fiscal reasons and is not at present being considered for funding in the form originally proposed. During this period, other nations have taken over the lead from the United States in the important field of millimeter-wave studies of atoms and molecules in space. The field of VLBI, which was also pioneered in the United States, represents an outstanding opportunity for maintaining leadership in this exciting field of science.

New Technology Telescope (NTT) of the 15-Meter Class

In considering this project, the Astronomy Survey Committee wrote: "The Committee finds the scientific merit of this instrument to be as high as that of any other facility considered and emphasizes that its priority ranking (No. 3 among major new programs) does not reflect its scientific importance but rather its state of technological readiness. The design studies needed before NTT can be constructed are of the highest priority and should be undertaken immediately." Thus, the Committee emphasized the importance of an immediate start toward the ultimate goal of NTT. The NTT has been studied at a low level for the past several years; because of the technological challenge of the NTT project, an augmentation of these studies to the level of $2 million/year in each of FY 1984 and 1985 will be required to permit a final design to be selected by FY 1986.

A ground-based telescope in the 15-meter class will make powerful contributions to optical and infrared astronomy, particularly through spectroscopic observations of faint stars and galaxies that cannot practicably be carried out with present instruments and through infrared observations with high angular resolution. New technology developed during the 1970's has made it feasible to build telescopes on this scale at a cost far lower than would have been possible only a few years ago. The capabilities of NTT will complement those of Space Telescope, which has higher angular resolution but less light-gathering power in the optical region of the spectrum, and of SIRTF, which has higher sensitivity but lower angular resolution in the infrared spectral range. The spectroscopic studies required to follow up on the discoveries by ST can be carried out only with an instrument having the aperture of NTT.

Moderate New Program

Augmentation to the NASA Explorer Program

Among moderate new programs recommended for the 1980's, the Astronomy Survey Committee listed an augmentation to the NASA Explorer program as the highest priority: ". . . the flight of new Explorer missions has in recent years fallen much below the rate needed for healthy advance. The rate will decline even more drastically during the early 1980's if present budget levels are not increased. The Astronomy Survey Committee thus recommends an immediate and substantial augmentation to the Explorer program to restore it to at least the real level of effort of 1970." An augmentation of $20 million in FY 1984 represents an important first step in response to this recommendation. Such funding will permit the accelerated development and launch of three Explorer missions currently in various stages of preparation.

1. The Cosmic Background Explorer (COBE), now under development, will test the big-bang model of the Universe by extremely precise measurements of the cosmic microwave background radiation.
2. The Extreme Ultraviolet Explorer (EUVE), at present under study, will conduct the first all-sky survey of EUV sources, closing an important gap in our knowledge of the cosmic electromagnetic spectrum.
3. The X-Ray Timing Explorer (XTE), also now under study, will permit studies of the variability of x-ray sources on time scales from milliseconds to years, providing new constraints on models of neutron stars, accretion disks around collapsed stars, x-ray bursters, and quasars.

Appendix A

[Reprinted from Science, August 20, 1982, Volume 217, No. 4561, p. 691. Courtesy, American Association for the Advancement of Science.]

Astronomy and Astrophysics in the United States

A recently issued report* on astronomy begins: "Nature offers no greater splendor than the starry sky on a clear, dark night. Silent, timeless, jeweled with the constellations of ancient myth and legend, the night sky has inspired wonder throughout the ages."

For most of human history, leadership in studying the heavens has resided elsewhere, but during the 20th century the United States has been the world center of astronomy. This preeminence has been due to good financial support and the imaginative creation of innovative observing equipment. The capabilities of excellent optical telescopes, developed during the first half of this century, were later extended by equipment designed for observing throughout the electromagnetic spectrum. Leading supporters of the development of optical telescopes were the Carnegie Institution of Washington, with its 2.5-meter telescope at Mount Wilson, and the Rockefeller Foundation, which gave the California Institute of Technology funds to build the 5-meter telescope at Mount Palomar. More recently, the National Science Foundation has become a major funder of ground-based astronomy, while NASA has provided excellent facilities in space. The United States has led in exploration of the solar system. In addition, it has launched space vehicles that have permitted observations which could not be achieved from the earth because of absorption of radiation in the atmosphere. The Space Telescope, to be launched in 1985, will be free from atmospheric inhomogeneities that blur sources of light and will be capable of high resolution of objects.

By 1970, generous support of American astronomy had led to many discoveries, including Hubble's expanding universe, time and celestial distance scales, quasars, x-ray sources, high-energy celestial gamma rays, the cosmic microwave background radiation, and polyatomic molecules in interstellar clouds. Discoveries during the 1970's included neutron stars accreting matter from nearby companion stars, hot intergalactic gas whose mass rivals that of the galaxies themselves, vast regions of interstellar gas heated to hundreds of thousands of degrees by shock waves from supernova

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***Astronomy and Astrophysics for the 1980's*, volume 1, *Report of the Astronomy Survey Committee* (National Academy Press, Washington, D.C., 1982).

explosions, and a gravitational lens effect observed as the splitting of light from a distant quasar as the light passed through an intervening galaxy.

The contributions of American astronomy are important and impressive. However, leadership cannot be maintained by resting on our laurels. Continuing preeminence of the United States will be dependent on well-trained people, who are provided with superior equipment.

The astronomical community has made a careful and searching study of opportunities and needs for support for the 1980's. Through extensive consultation and deliberation, a consensus has been achieved. The major new equipment recommended includes (i) an advanced X-ray Astrophysics Facility operated in space; (ii) a Very-Long-Baseline Array of radio telescopes; (iii) a New Technology Telescope, 15 meters in diameter, for ground-based studies in the optical and infrared regions of the spectrum; and (iv) a Large Deployable Reflector in space. All of these proposals would substantially extend the capabilities of astronomy. For example, the Very-Long-Baseline Array would have an angular resolution 100 times better than that of any other image-forming telescope at any wavelength. It would yield detailed radio images of quasars, the nuclei of galaxies, and features of interstellar molecular clouds and other astronomical objects. The first and third items above would be important for many studies, perhaps the most interesting being the examination of extremely distant objects whose radiation was emitted early in the history of the universe.

The report is well constructed and readable. It states well the case for additional expenditures for astronomy. Because of current budgetary problems, its recommendations may not be quickly accepted. However, it is designed to be relevant to the 1980's and at least part of it will surely be ultimately implemented.—PHILIP H. ABELSON

Appendix B

[Reprinted from Astronomy and Astrophysics for the 1980's, Volume 1, Report of the Astronomy Survey Committee (Washington, D.C.: National Academy Press, 1982), pp. 13-22.]

The Astronomy Survey Committee takes note at the outset of the support provided to U.S. astronomy and astrophysics over the past decades through the scientific programs of the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and other federal agencies. This support has enabled U.S. astronomical research to maintain an overall position of world leadership and has vastly widened our horizons for exploration of the Universe.

The programs recommended in this report have been selected from research activities that were, at the beginning of the Survey, candidates for implementation in fiscal year 1983 and beyond. Before presenting a summary of its recommendations, however, the Committee wishes to emphasize the importance of approved, continuing, and previously recommended programs to the progress of astronomical research during the remainder of the decade. The present Committee's recommendations take explicit account of such programs and build upon them.

The Committee calls particular attention to the need for support of the following approved and continuing programs, for which the order of listing carries no implication of priority: Space Telescope and the associated Space Telescope Science Institute; second-generation Space Telescope instrumentation; the Gamma Ray Observatory; NASA level-of-effort observational programs, including research with balloons, aircraft, and sounding rockets, together with the Explorer and Spacelab programs; the Solar Optical Telescope and the Shuttle Infrared Telescope Facility for Spacelab; facilities for the detection of neutrinos from the solar interior; federal grants in support of basic astronomical research at U.S. universities; and programs at the National Astronomy Centers. The 25-Meter Millimeter-Wave Radio Telescope, which was recommended in an earlier form in the Greenstein report, has not yet been implemented. The present status of these approved, continuing, and previously recommended programs is described later in this chapter; their importance for the health of U.S. astronomy in the 1980's is discussed in Chapter 4.

SUMMARY OF THE RECOMMENDED PROGRAM

The Astronomy Survey Committee recommendations for a program in astronomy and astrophysics for the 1980's fall into three general categories:

Prerequisites for new research initiatives;
New programs; and
Programs for study and development.

As noted in the Preface, the observational components of these recommendations are restricted to remote sensing from the Earth or its vicinity. A background and overview of the recommendations follows later in this chapter.

Prerequisites for New Research Initiatives

In order to be effective, the recommended new research initiatives for the coming decade must be supported by a set of Prerequisites that apply to both the gathering and the analysis of the data produced. These Prerequisites are essential for the success of major programs but are inexpensive by comparison. Although significant support already exists for each, the Committee strongly recommends substantial augmentations in the following areas, in which the order of listing carries no implication of priority.

A. *Instrumentation and detectors*, to utilize the latest technology to enhance the efficiency of both new and existing telescopes in the most cost-effective manner;

B. *Theory and data analysis*, to facilitate the rapid analysis and understanding of observational data;

C. *Computational facilities*, to promote data reduction, image processing, and theoretical calculations;

D. *Laboratory astrophysics*, to furnish the atomic, molecular, and nuclear data essential to the interpretation of nearly all astronomical observations; and

E. *Technical support at ground-based observatories*, to ensure that modern astronomical instrumentation is maintained in the best condition permitted by the state of the art.

A detailed consideration and justification of these Research Prerequisites appears in Chapter 5.

New Programs

The Astronomy Survey Committee recommends the approval and funding of new programs in astronomy and astrophysics for the 1980's. These have been arranged into three categories according to the scale of resources required.

A. *Major New Programs* The Committee believes that four major programs are critically important for the rapid and effective progress of astronomical research in the 1980's and is unanimous in recommending the following order of priority:

1. *An Advanced X-Ray Astrophysics Facility* (AXAF) operated as a permanent national observatory in space, to provide x-ray pictures of the Universe comparable in depth and detail with those of the most advanced optical and radio telescopes. Continuing the remarkable development of x-ray technology applied to astronomy during the 1970's, this facility will combine greatly improved angular and spectral resolution with a sensitivity up to one hundred times greater than that of any previous x-ray mission.
2. *A Very-Long-Baseline* (VLB) *Array* of radio telescopes designed to produce radio images with an angular resolution of 0.3 milliarcsecond. Among many potential applications of profound importance, this instrument will probe the small-scale structure surrounding the enigmatic energy sources in the cores of quasars and active galactic nuclei and will directly determine the distance scale within our Galaxy with unprecedented accuracy.
3. *A New Technology Telescope* (NTT) of the 15-m class operating from the ground at wavelengths of 0.3 to 20 μm, to provide a tenfold increase in light-gathering capacity at visual wavelengths and a hundredfold increase in speed for spectroscopy at infrared wavelengths, with application to a very wide range of scientific problems. The Committee finds the scientific merit of this instrument to be as high as that of any other facility considered and emphasizes that its priority ranking does not reflect its scientific importance but rather its state of technological readiness. *The design studies needed before* NTT *can be constructed are of the highest priority and should be undertaken immediately.*
4. *A Large Deployable Reflector* in space, to carry out spectroscopic and imaging observations in the far-infrared and submillimeter wavelength regions of the spectrum that are inaccessible to study from the ground, thus extending the powerful capabilities of NTT to these longer wavelengths. Such an instrument, in the 10-m class, will present unprecedented opportunities for studying molecular and atomic processes that accompany the formation of stars and planetary systems.

B. *Moderate New Programs* In rough order of priority, these are:

1. *An augmentation to the* NASA *Explorer program*, which remains a flexible and highly cost-effective means to pursue important new space-science opportunities covering a wide range of objects and nearly every region of the electromagnetic spectrum.

2. *A far-ultraviolet spectrograph in space,* to carry out a thorough study of the 900–1200-Å region of the spectrum, important for studies of stellar evolution, the interstellar medium, and planetary atmospheres.
3. *A space* VLB *interferometry antenna* in low-Earth orbit, to extend the powerful VLBI technique into space in parallel with the rapid completion of a ground-based VLB Array, in order to provide more detailed radio maps of complex sources, greater sky coverage, and higher time resolution than the Array can provide alone.
4. *The construction of optical/infrared telescopes in the 2–5-m class,* to observe transient phenomena, conduct long-term survey and surveillance programs, provide crucially needed ground-based support to space astronomy, and permit the development of instrumentation under realistic observing conditions. The Committee particularly encourages federal assistance for those projects that will also receive significant nonfederal funding for construction and operation.
5. *An Advanced Solar Observatory* in space, to provide observations of our Sun—the nearest star—simultaneously at optical, extreme ultraviolet, gamma-ray, and x-ray wavelengths, to carry out long-term studies of large-scale circulation, internal dynamics, high-energy transient phenomena, and coronal evolution.
6. *A series of cosmic-ray experiments* in space, to promote the study of solar and stellar activity, the interstellar medium, the origin of the elements, and violent solar and cosmic processes.
7. *An astronomical Search for Extraterrestrial Intelligence* (SETI), supported at a modest level, undertaken as a long-term effort rather than as a short-term project, and open to the participation of the general scientific community.

C. *Small New Programs* The program of highest priority is:

- An antenna approximately 10 m in diameter for submillimeter-wave observations, at an excellent ground-based site.

Other programs of outstanding scientific merit, in which the order of listing carries no implication of priority, are as follows:

- A spatial interferometer for observations of high angular resolution in the mid-infrared region of the spectrum;
- A program of high-precision optical astrometry; and
- A temporary program to maintain scientific expertise at U.S. universities during the 1980's through a series of competitive awards to young astronomers.

Detailed discussion and justification of the New Programs appears in Chapter 6.

Programs for Study and Development

Planning and development are often time-consuming, especially for large projects. It is therefore important during the coming decade to begin study and development of programs that appear to have exceptional promise for the 1990's and beyond. Projects and study areas recommended by the Committee in this category include the following, in which the order of listing carries no implication of priority:

A. Future x-ray observatories in space;
B. Instruments for the detection of gravitational waves from astronomical objects;
C. Long-duration spaceflights of infrared telescopes cooled to cryogenic temperatures;
D. A very large telescope in space for optical, ultraviolet, and near-infrared observations;
E. A program of advanced interferometry in the radio, infrared, and optical spectral regions;
F. Advanced gamma-ray experiments; and
G. Astronomical observatories on the Moon.

Detailed discussion of the Programs for Study and Development appears in Chapter 7.

ESTIMATED COST OF THE RECOMMENDATIONS

In order to establish the overall scale of the recommended total program, the Committee gives in Table 2.1 its own approximate estimates of the requirements for new funding over the next 10 years in millions of 1980 dollars. Funds for projects to be supported by NASA represent research-and-development funds within NASA's Office of Space Science and Applications (OSSA); funds for projects to be supported by NSF represent total cost to NSF. Operating costs are included for those facilities expected to become operational in the 1980's.

The funding entries for the Prerequisites for New Research Initiatives represent augmentations to the present levels of support for these activities within NSF and NASA. As it is expected that the two agencies will work together to coordinate support for the Prerequisites, specific agency responsibility is not indicated in the following table. However, since the Prerequisites provide support to space- and ground-based research at comparable levels, the Committee anticipates that the funding augmentations to be provided by NASA and NSF will be roughly equal in magnitude.

In the cases of the New Programs, the division between space- and ground-based projects is clear. Funds listed for the Explorer program represent an augmentation to NASA's level-of-effort budget for that program; the operations costs listed for ground-based projects, together with the temporary program to maintain scientific expertise at U.S. universities, represent further augmentations to the operations budget of NSF's Astronomy Division. Remaining New

TABLE 2.1 Requirements for New Funding

	(Millions of 1980 Dollars)
PREREQUISITES FOR NEW RESEARCH INITIATIVES	
A. Instrumentation and detectors (doubling of present $15 million/year level of effort by increments over 10 years)	$ 75
B. Theory and data analysis (augmentation by $5 million/year)	50
C. Computational facilities (30 minicomputer systems installed at a rate of 5 systems/year, including operations)	20
D. Laboratory astrophysics (augmentation by $2.5 million/year)	25
E. Technical support at ground-based observatories, including 40 new support positions	20
DECADE TOTAL, PREREQUISITES	$190
NEW PROGRAMS	
A. *Major New Programs* In order of priority:	
1. Advanced X-Ray Astrophysics Facility (AXAF)	$500
2. Very-Long-Baseline (VLB) Array (including $15 million for operations)	50
3. New Technology Telescope (NTT)	100
4. Large Deployable Reflector in space	300
Decade Subtotal	$950
B. *Moderate New Programs* In rough order of priority:	
1. Augmentation to Explorer satellite program	$200
2. Far-ultraviolet spectrograph in space	150
3. Space VLB interferometry antenna	60
4. Optical/infrared telescopes in the 2–5-m class	20
5. Advanced Solar Observatory in space	200
6. Cosmic-ray experiments	100
7. An astronomical Search for Extraterrestrial Intelligence (SETI)	20
Decade Subtotal	$750
C. *Small New Programs* Of highest priority:	
• 10-m submillimeter-wave radio antenna (including $2 million for operations)	$ 4
Other important programs:	
• Spatial interferometer for the mid-infrared (including $1 million for operations)	3
• High-precision optical astrometry program	3
• Temporary program to maintain scientific expertise at U.S. universities	10
Decade Subtotal	$ 20
DECADE TOTAL, NEW PROGRAMS	$1,720

Program costs represent new-funding requirements for either NASA (new starts within OSSA) or NSF (major construction within the Astronomy Division).

The cost estimates for AXAF and the VLB Array were derived with the help of individual scientists participating in current studies and are based on reasonably complete rough designs. The actual cost of NTT, however, cannot be estimated until further studies indicate which of several alternative conceptual designs will be most cost-effective; the figure given in Table 2.1 is meant as a limit that the Committee recommends should not be substantially exceeded. The estimated cost of the Large Deployable Reflector in space is highly uncertain because instrumentation of this type has not yet been developed and launched. Most of the costs estimated for the Moderate New Programs should be reasonable approximations, as they are based on experience with previous instruments of a similar nature. The costs given for the augmentation to the NASA Explorer program and for SETI, however, should be regarded as target figures for the level of effort the Committee finds appropriate.

The total cost in new funding estimated for the Prerequisites and New Programs together is about $1.9 billion in 1980 dollars. By comparison, the Greenstein report (1972) recommended new programs with an estimated cost of $844 million in 1970 dollars, or approximately $1.7 billion in 1980 dollars, and most of those programs were in fact implemented. *The program recommended here for the 1980's is thus roughly comparable in scale with that actually carried out during the 1970's on the basis of the recommendations of the Greenstein report.*

The Committee wishes to emphasize, however, that the present recommendations will require substantial increases in the budget of the Astronomy Division of NSF, the agency primarily responsible for the support of ground-based astronomy. If, as anticipated, NSF will provide roughly half of the additional funds required for the Prerequisites for New Research Initiatives, an increase of about 30 percent in the Astronomy Division's operations budget over the real level of expenditures during the 1970's will be required for NSF to carry out its share of the recommended program over the next decade. Funds needed by NSF for major construction over the next 10 years will also be substantially higher than those expended during the 1970's, which saw the completion of only one major project, the Very Large Array, at a cost of $78 million. *The Astronomy Survey Committee believes that these increases in the NSF budget for ground-based astronomy are essential to maintain an effective partnership with space astronomy during the 1980's.*

BACKGROUND AND OVERVIEW

The Greenstein Report

The publication of *Astronomy and Astrophysics for the 1970's* (the Greenstein report) by the National Academy of Sciences in 1972 had a powerful impact on the development of U.S. astronomy and astrophysics during 1972–1982. The federal government on the whole responded positively to its recommendations, with the result that the facilities available to U.S. astronomers have enabled them to remain at the frontiers of research. Here we review the responses to the recommendations of that report and their impact on the progress of science.

Radio Astronomy and the VLA The highest-priority recommendation of the Greenstein report was the construction of a Very Large Array (VLA) radio telescope, together with increased support for smaller facilities. Funded by NSF, the VLA was constructed in stages during the 1970's and was formally dedicated in 1980; by far the largest and most complex ground-based astronomical facility established to date, the VLA was completed on schedule and within budget. VLA studies of radio sources are already having a large impact on both Galactic and extragalactic astronomy (see, for example, the cover of this report).

The recommended increase in funding for smaller radio-astronomical facilities did not materialize, however, nor has funding yet been provided for a recommended millimeter-wave radio telescope, then projected to have a diameter of 65 m and to be operable at wavelengths down to 3 mm. Since the publication of the Greenstein report, the study of interstellar molecules at millimeter wavelengths has yielded insight into the process of star formation; as the science has progressively moved to shorter wavelengths, there has now evolved a need for a smaller, more precisely figured telescope of 25-m diameter, still offering high sensitivity and spatial resolution but operable at wavelengths down to 1 mm. The recommendation for a large centimeter-wave antenna was not implemented, although existing facilities for observations at wavelengths longer than 1 cm have been maintained and in some cases upgraded.

Optical Ground-Based Astronomy The second-priority recommendation was for a variety of steps to enhance the capability available to U.S. optical astronomers. A key proposal was the development and construction of a multiple-mirror telescope (MMT) with aperture equivalent to that of a conventional telescope in the 3.8–5.0-m range; this project was to be followed by the construction of a larger MMT, of 10–15-m aperture, if that proved feasible, or by a conventional telescope of 5-m aperture if it did not. A 4.5-m MMT has in fact been developed jointly by the Smithsonian Institution and the University of Arizona, becoming operational in 1979. However, neither a larger MMT nor a conventional 5-m telescope has been funded, with the result that the largest instrument available to U.S. optical astronomers is still the 5-m Hale telescope on Mt. Palomar, which went into operation 35 years ago. As a result, optical spectroscopy of the faintest galaxies and quasars discovered by radio and x-ray astronomers has not kept pace with new discoveries, even though these extremely distant objects are of great interest because of their bearing on the nature of cosmic evolutionary processes early in the history of the Universe.

The recommendation also called for equipping existing telescopes with advanced electronic detectors and controls. Although major progress was made in the development of such devices during the 1970's, they have so far been provided to only a few major observatories. The capability of instruments now available for use on most of the nation's optical telescopes still lags far behind state-of-the-art technology.

The Greenstein report furthermore recommended that three telescopes in the 2.5-m class be constructed for a variety of purposes. As none of these has been funded, all the nation's major optical telescopes are heavily oversubscribed.

Infrared Astronomy The third-priority recommendation called for an across-the-board increase in support for infrared astronomy, which at that time was beginning to demonstrate its great importance. Support has increased substantially, through the funding of two major ground-based infrared telescopes (the 2.3-m University of Wyoming Infrared Observatory reflector and the 3-m Infrared Telescope Facility operated by NASA on Mauna Kea), the Kuiper Airborne Observatory program, and a balloon program. An international Infrared Astronomy Satellite (IRAS), scheduled for launch in 1982, will carry out a comprehensive, far-infrared survey of the sky, as called for in the Greenstein report.

Appendix C

[Reprinted from Astronomy and Astrophysics for the 1980's, Volume 1, Report of the Astronomy Survey Committee (Washington, D.C.: National Academy Press, 1982), pp. 112-113.]

The Shuttle Infrared Telescope Facility (SIRTF)

The proposed SIRTF will be the cornerstone of research in infrared astronomy during the 1980's. The Astronomy Survey Committee joins with the Space Science Board's Committee on Space Astronomy And Astrophysics (*A Strategy for Space Astronomy and Astrophysics for the 1980's*, National Academy of Sciences, Washington, D.C., 1979) in recommending this facility as the first major infrared telescope in space.

SIRTF will permit investigations over the enormous range of wavelengths from 2 to 300 μm. For some important types of observations it will, because of its cryogenically cooled optics, yield a sensitivity gain of 1000 over the largest existing ground-based and airborne infrared telescopes; this gain in sensitivity is so large that it is not unreasonable to expect that SIRTF will make important and unexpected discoveries. The multiple, interchangeable focal-plane instruments planned for SIRTF will moreover greatly increase our ability to explore the evolution of distant extragalactic sources, the physical properties and chemical composition of molecular clouds and regions of star formation, the nature of cometary nuclei and asteroids, and the structure of planetary atmospheres. For example, SIRTF will be able to detect infrared sources at the limits of the observable Universe; on one Shuttle flight, it could gather information on sources of both large and small red shift, thus permitting a comparison of the energetics of quasars and galaxies at the earliest epochs of the Universe with those at the present epoch. Because of its relatively wide field of view, SIRTF will also be able to carry out efficient surveys of infrared sources that will help to optimize the observing programs of larger instruments, such as the New Technology Telescope (NTT), the VLB Array, and a Large Deployable Reflector (LDR) in space, which have narrower fields of view.

SIRTF should be an early and frequently flown payload on Shuttle sortie missions. It has such high sensitivity that very extensive infrared observations can be accomplished even within the relatively brief, 7-day profile of an early Shuttle flight; reflight on the Shuttle makes it possible to fly SIRTF with continually improved focal-plane instrumentation and detectors. Eventually, however, SIRTF flights of longer duration will be needed to realize the full potential of this remarkable facility, and the study of such flights is recommended in Chapter 7.

Appendix D

[Reprinted from Astronomy and Astrophysics for the 1980's, Volume 1, Report of the Astronomy Survey Committee (Washington, D.C.: National Academy Press, 1982), pp. 135-136.]

2. *A Very-Long-Baseline (VLB) Array of Radio Telescopes*

The Astronomy Survey Committee recommends the construction of a ground-based Very-Long-Baseline (VLB) Array of radio telescopes designed to produce images with an angular resolution of 0.3 milliarcsecond. Because the Array utilizes proven technology, this project may be begun immediately after completion of final management and design studies.

Extraordinarily high angular resolution is now possible at radio frequencies. Precision atomic clocks, more sensitive and reliable receivers, high-speed tape recorders, sophisticated image-processing techniques, and modern antennas now make it feasible to build a radio array with the angular resolution of a telescope covering an entire continent. This may be done by synchronizing the operation of about ten widely spaced antennas of approximately 25-m diameter, whose outputs are recorded and later combined in a central computer.

This VLB Array will produce high-quality radio images capable of resolving features down to 0.3 milliarcsecond (the size of a dime in New York as seen from Los Angeles). This is a hundred times better angular resolution than that of any other image-forming telescope at any wavelength and will yield detailed new radio images of a wide range of astronomical objects at the frontiers of modern astrophysical research. These include quasars and the nuclei of galaxies, features of interstellar molecular clouds, the center of our Galaxy, and a variety of energetic Galactic objects such as x-ray, binary, and flare stars. The high angular resolution of the VLB Array will permit the direct study of small-scale structure surrounding the central regions of quasars and stars in the process of formation. Through the method of statistical parallaxes, it will furthermore permit direct measurements of distances to many objects throughout our Galaxy and even to some in nearby galaxies. The VLB Array can also be applied to important problems in Earth science (including precision geodesy and geophysics), to the navigation of interplanetary spacecraft, and to tests of the General Theory of Relativity.

Although the VLB Array is a complex and sophisticated instrument, it will make use of proven concepts and instrumentation. Construction should begin immediately upon completion of management and design studies with the building of the antennas and the development of the data-reduction system and other instrumentation. Collaboration with groups in other countries, particularly in Europe and North America, would improve the performance of the instrument by increasing the resolution even further (particularly in the north-south direction) and by improving the image quality at low declinations.

Mr. **Walgren**. Thank you very much. I think you have exhausted me, and we ought to stop at this point. We will look forward to some future comments and thoughts exchanged with you. We appreciate the time you have given to the committee. Thank you very much.

[Whereupon, at 5:24 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

[Material bearing on the subject of today's hearing follows:]

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March 2, 1983

Congressman Doug Walgren, Chairman
Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Doug,

You asked me about the ideas that Jacques Cousteau presented to the Subcommittee and I am not sure that I gave you a very good answer. I said that ideas like his are hard to implement, but I didn't say why.

Bob Reynolds, Noye Johnson and I were involved in a project in the western United States that attempted to do in a microcosm what Cousteau was talking about in a macrocosm. We were part of a multidisciplinary team that studied a part of the Colorado River system and the effect of human activity on this system. At that time there was a program in NSF called RANN (Research Applied to National Needs) and the program was formed under its umbrella. I think that the program was quite successful; the results were useful and the participants learned a great deal, not only about the system, but also about interactions among the disciplines represented.

I helped Orson Anderson get this program started and served on the Steering Committee of the project. I think the project worked because the leadership was strong; the participants were mostly fairly senior and confident of their positions within their own disciplines. Junior people have more to worry about and it is riskier for them to venture out of the main line of their fields. There was a focus to the efforts and there were many late night sessions in which we attempted to explain to those outside our disciplines how our work was contributing to the principal thrust.

I enclose a study of the sociology of the Project, done by Orson, and thus not totally unbiased. I thinks it lays out pretty well the problems and how they they were dealt with. They were resolvable on this scale; they are formidable on the scale of which Cousteau spoke.

Regards,

Charles L. Drake
Professor of Earth Sciences

CLD/abc

cc: Orson Anderson

LAKE POWELL RESEARCH PROJECT BULLETIN

BULLETIN EDITORS
Priscilla C. Grew and Orson L. Anderson

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Jeni M. Varady

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400

MANAGEMENT OF SCIENTIFIC COLLABORATION IN THE LAKE POWELL RESEARCH PROJECT

Orson L. Anderson

Institute of Geophysics and Planetary Physics
University of California
Los Angeles, California 90024

October 1975

LAKE POWELL RESEARCH PROJECT

The Lake Powell Research Project (formally known as Collaborative Research on Assessment of Man's Activities in the Lake Powell Region) is a consortium of university groups funded by the Division of Advanced Environmental Research and Technology in RANN (Research Applied to National Needs) in the National Science Foundation.

Researchers in the consortium bring a wide range of expertise in natural and social sciences to bear on the general problem of the effects and ramifications of water resource management in the Lake Powell region. The region currently is experiencing converging demands for water and energy resource development, preservation of nationally unique scenic features, expansion of recreation facilities, and economic growth and modernization in previously isolated rural areas.

The Project comprises interdisciplinary studies centered on the following topics: (1) level and distribution of income and wealth generated by resources development; (2) institutional framework for environmental assessment and planning; (3) institutional decision-making and resource allocation; (4) implications for federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) impact of development on demographic structure; (6) consumptive water use in the Upper Colorado River Basin; (7) prediction of future significant changes in the Lake Powell ecosystem; (8) recreational carrying capacity and utilization of the Glen Canyon National Recreational Area; (9) impact of energy development around Lake Powell; and (10) consequences of variability in the lake level of Lake Powell.

One of the major missions of RANN projects is to communicate research results directly to user groups of the region, which include government agencies, Native American Tribes, legislative bodies, and interested civic groups. The Lake Powell Research Project Bulletins are intended to make timely research results readily accessible to user Groups. The Bulletins supplement technical articles published by Project members in scholarly journals.

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ABSTRACT

Some problems of operating a multidisciplinary consortium engaged in assessing regional environmental impact are defined. The Lake Powell Research Project is such a consortium dealing with energy and water management problems in the Four Corners region of the United States. The management chosen by the Project leaves major decisions to a Steering Committee rather than to a Project Director. The advantages and disadvantages of this type of management of a consortium are analyzed. Special consideration is given to problems of integrating work of various disciplines and to the conveyance of research results to user groups.

(The complete study may be viewed in the Subcommittee offices or is available, as noted on the title page reprinted here, from the Institute of Geophysics and Planetary Physics, University of California, LA.)

1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 8, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcomittee met, pursuant to recess, at 2:25 p.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Brown, Valentine, MacKay, Gregg, Skeen, Bateman, Sensenbrenner, and Boehlert.

Mr. Walgren. Let me call the meeting to order, and apologize for starting a little late. That vote came at the wrong time for us to get going directly.

This is the third day of authorization hearings for the National Science Foundation, and we want to return to the subject of instrumentation at the Nation's universities. In the past NSF authorization hearings, this subcommittee has heard of a growing need to replace obsolescent and wornout research equipment in the universities and colleges. The cost of such an upgrading program has been estimated to be between $2 and $4 billion.

These figures may in fact be too low, as a recent study of the National Society of Professional Engineers estimates over $1 billion will be required to restore engineering instructional laboratories to their 1971 status. If the necessary additions to accommodate the growth in student enrollment in engineering are included, that cost then rises substantially.

In his testimony before the full Science and Technology Committee, Dr. Keyworth, the President's science adviser, said that he expects that nearly $400 million of the 1984 basic research budget will go to purchase and replace instrumentation. NSF will be supplying about 45 percent of these funds with a $180 million initiative. This subcommittee is pleased to see this response by the administration to a problem that the Congress has had a growing appreciation of.

Today we want to hear not only how NSF plans to use their instrumentation funds, but we also will be interested to hear from distinguished groups of university and industry witnesses. These gentlemen will address some of the non-Federal programs underway which could revitalize university research facilities. There certainly are exciting things being done by the universities alone and through university and industry cooperative programs, and we want to know more about them. We all feel that this problem is probably one that is certainly beyond the scope of Government to solve, and therefore we have to encourage to the greatest degree possible these kinds of joint efforts by universities and the private sector.

We appreciate your coming. Dr. Knapp, it is good to see you again. We feel we are using a lot of your time these days but it is very helpful to the committee and we are most appreciative of the effort you have given to presenting your views and the direction you see that the National Science Foundation should go, particularly as you start your administration there. Therefore, thank you for being back. We look forward to your testimony.

Dr. **Knapp**. Thank you, Mr. Chairman.

Mr. **Walgren**. Let me ask, just at the outset, whether anybody else would like to have any opening statements or comments?

[No response.]

Mr. **Walgren** [continuing]. Proceed, Dr. Knapp.

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. **Knapp**. I would like to submit my testimony for the record and summarize.

Mr. **Walgren**. That would be most appreciated.

Dr. **Knapp**. Research instrumentation—whether it is the mass spectrometer of the chemist, the electron microscope of the biologist, or the radio telescope of the astronomer—provides the essential means through which the scientist asks questions and obtains answers from nature. Instruments are the eyes through which a researcher views and produces information or data about the world of interest to him and his colleagues. Modern computers, in turn, enable the scientist to handle and interpret previously unimaginable amounts of complex data, as well as to construct and manipulate models which simulate the behavior of complex systems.

When I appeared before your committee last week, I had an opportunity to discuss several fields—astronomy, oceanography, and the atmospheric and earth sciences—which are characterized by a high dependence on instrumentation and research facilities. It is the case, however, that investigators in virtually every field of science and engineering are increasingly dependent upon research instrumentation and computers if they are to conduct leading-edge research in their disciplines. Let me give you two brief examples of what improvements in instrumentation can mean for a field of science.

We are all aware of how solid-state devices have revolutionized communications and computing over the past 20 years. A much less widely known product of solid-state electronics is the charge-coupled detector array. These arrays of photosensitive diodes allow astronomers to detect and map light sources in the universe hundreds of times fainter than those previously observable.

In addition to this major increase in sensitivity, the output of a detector is an electrical signal that is easily digitized for imaging and further computer processing. The images obtained from optical

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telescopes can now be compared directly with those maps obtained by radiotelescopes.

Once the concepts underlying these detectors were initially outlined and understood, much of their early development and testing was supported by the National Aeronautics and Space Administration as a part of its development of the space telescope. Today virtually every major observatory has a charge-coupled detector in use or being tested.

All natural phenomena are intrinsically related. The results of research in one field—say, physics—can and do have unexpected and revolutionary impacts on work in other disciplines. A prime example is the phenomenon of nuclear magnetic resonance investigated by the physicists Bloch at Stanford and Purcell at Harvard, both of whom received the Nobel Prize for their work.

Bloch and Purcell were working independently on an esoteric problem—the behavior of substances in a magnetic field when they are irradiated by radio frequency waves. They predicted and observed that water subjected to these conditions would absorb energy, and that the absorption of energy was characteristic of the elements making up the molecule and its local environment.

Soon the phenomenon of nuclear magnetic resonance, originally studied for its own sake, was developed into a nuclear magnetic resonance spectrometer, a tool for probing the nature of molecules themselves. The application of such spectroscopy to problems in chemistry, biochemistry, and molecular biology has revolutionized these fields.

Before the development of NMR, scientists used X-ray diffraction to study the three-dimensional structures of molecules. X-ray diffraction was, however, limited to molecules in the solid state. With NMR, it became possible for the first time to study the spatial structure of molecules in solution. Reactions could be monitored in cell or tissue under normal, abnormal, or diseased conditions. Previously it was necessary to kill or destroy the tissue. Biologists studied reactions in the intact liver, intact heart muscle, and in other tissues as they metabolized.

Moreover, it is now actually possible to map the interior of a tissue or organ using NMR imaging in a manner that is analogous to that used in CAT scanning. Thus, an exotic prediction based on a complex theoretical model far removed from the real world of biology and medicine developed, through the efforts of many physicists, chemists, and biologists, into an important tool for advancing the understanding of life processes.

As these two examples suggest, an investment in research instrumentation increases both the quality of the science that can be pursued and the productivity and efficiency of the investigator. In addition, when this equipment is located on a university or college campus it contributes significantly to the training of graduate students who will become the future scientists and engineers staffing the industrial, academic, and Government institutions.

In the past few years, there has been a growing realization that the United States is underinvesting in state-of-the-art instrumentation and facilities at academic institutions. Although the exact magnitude of the problem cannot be determined at present, numerous indicators all seem to point in the same direction: The problem is large and involves most areas of science and engineering in most of the major research universities.

A study by the American Association of Universities in 1981, for example, examined the instrumentation and facilities needs of 6 disciplines in 15 leading universities. These universities reported that they alone would have to spend almost $800 million over 3 years just to provide modern equipment for their existing faculty. The AAU study suggested that as much as $4.4 billion would be required over a 3- to 5-year period to fully upgrade instrumentation at the 100 leading academic research institutions.

More recently, at the urging of this committee, the Foundation has begun to develop statistically reliable indicators of trends in the cost, condition, and use of research instrumentation in the universities as a basis for projecting current and future needs. While the results from the first phase of this study will not be available until later this year, the Foundation has already completed a pilot study in 38 institutions in 4 subfields—organic chemistry, cell biology, solid-state physics, and electrical engineering.

This pilot study found about one-fourth of the research equipment was 10 years old; one-fourth was 5 to 9 years old; and one-half was less than 5 years old. Sixty-five percent of the total equipment had been acquired partly or entirely with Federal funds.

In fiscal year 1983, the Department of Defense announced a special $30 million program aimed at upgrading academic research instrumentation. In response to this announcement, the Department received over $600 million in proposals, another indication of the potential magnitude and importance of the problem.

The Foundation's programs support the purchase and operation of research instrumentation and associated facilities in several modes. The most general and common way is to provide a single investigator with the instrument required in connection with a peer-reviewed research project. More expensive instruments for multi-user, multi-group projects may be requested through special programs such as the astronomical, biological, chemical, and materials research instrumentation programs.

Between fiscal years 1978 and 1980, NSF established 14 regional instrumentation facilities intended to make costly instrumentation accessible to a large number of qualified users, including those at smaller institutions.

Finally, the Foundation supports a limited number of large-scale facilities, such as Kitt Peak National Observatory, the Academic Oceanographic Fleet, and the National Center for Atmospheric Research. My remarks before your committee last week demonstrated the significance of such facilities for research in the astronomical and geophysical sciences.

The fiscal year 1984 budget request places a high priority on the problem of increased need for research instrumentation in the Foundation's programs. It is estimated that support of research instrumentation for NSF as a whole will increase about 61 percent between fiscal years 1983 and 1984.

In fiscal year 1982, the Foundation organized the Interagency Working Group on University Research Instrumentation, with representatives from the Department of Defense, the Department of Health and Human Services, the Department of Energy, the Department of Agriculture, and the National Aeronautics and Space Administration. These agencies, with NSF, provide over 95 percent of Federal support of university research. They are acquiring further data on the state of university equipment, taking new initiatives within their research budgets to place greater emphasis on instrumentation, and making Federal laboratories more accessible to university researchers.

Many universities have begun to accept responsibility for improving their management of instrumentation and are about to embark on a major education effort to encourage new financial arrangements, equipment sharing, and more responsive university regulations and policies. In the past, interest was not an allowable cost to be included in university overhead. Now, interest on loans for the purchase of research equipment costing $10,000 or more is allowable.

The Economic Recovery Tax Act of 1981 provided incentives for manufacturers of scientific instruments to contribute research apparatus to institutions of higher education. The impact of this act on the behavior of equipment manufacturers is still unclear, because the tax provisions are complex and because they are just one set of many factors which affect the tax position of firms donating equipment to academic institutions.

The Foundation has experimented with encouraging private instrument manufacturers to make contributions of scientific instrumentation to universities. One effort resulted in gifts of computers to colleges and universities to facilitate the development of special courseware in precollege and undergraduate education. In another, major computer manufacturers gave NSF grantees substantial discounts on computers to be used in research in mathematics.

Sensitive to possible questions concerning the Federal role in arrangments of this sort, the National Science Board at its October 1982 meeting established a policy encouraging such arrangements and directing the Foundation to "avoid actions that would compromise the integrity of the NSF; avoid favoring or appearing to favor one manufacturer over another; and avoid inappropriate exploitation of NSF's reputation."

More recently, the Board also dealt with the question of possible commercial use of NSF-supported instrumentation in a statement adopted in January 1983 the statement emphasized, in part, that "* * * it is contrary to NSF's intent for grantees to use NSF-supported research instrumentation or facilities to provide service for a fee in direct competition with private companies that provide equivalent services." The Foundation is currently reviewing a notice which will be sent to universities and colleges later this year, outlining the guidelines for the use and operation of NSF-sponsored research instrumentation and facilities.

Mr. Chairman, I know you and the other members of this committee share my views on the critical importance of instrumentation for maintaining the quality of the scientific enterprise and for strengthening the training of future scientists and engineers. The Foundation's program for fiscal year 1984 will take an important step toward upgrading the present quality of available instrumentation in the colleges and universities. Also, the leadership role which the Foundation has played with other Federal agencies, the private sector, and universities themselves is one of great importance if we are to continue this advance.

Thank you.

[The prepared statement of Dr. Knapp follows:]

STATEMENT OF
DR. EDWARD A. KNAPP
DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
MARCH 8, 1983

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

RESEARCH INSTRUMENTATION -- WHETHER IT IS THE MASS SPECTROMETER OF THE CHEMIST, THE ELECTRON MICROSCOPE OF THE BIOLOGIST OR THE RADIO TELESCOPE OF THE ASTRONOMER -- PROVIDES THE ESSENTIAL MEANS THROUGH WHICH THE SCIENTIST ASKS QUESTIONS OF AND OBTAINS ANSWERS FROM NATURE. INSTRUMENTS ARE THE "EYES" THROUGH WHICH A RESEARCHER VIEWS AND PRODUCES INFORMATION, OR DATA, ABOUT THE WORLD OF INTEREST TO HIM AND HIS COLLEAGUES. MODERN COMPUTERS, IN TURN, ENABLE THE SCIENTIST TO HANDLE AND INTERPRET PREVIOUSLY UNIMAGINABLE AMOUNTS OF COMPLEX DATA AS WELL AS TO CONSTRUCT AND MANIPULATE MODELS WHICH SIMULATE THE BEHAVIOR OF VERY COMPLXS SYSTEMS. COMPUTER SIMULATION MODELS ARE INCREASINGLY SIGNIFICANT RESEARCH TOOLS IN SCIENTIFIC FIELDS AS DIVERSE AS ECONOMICS AND ATMOSPHERIC SCIENCE.

When I appeared before your Committee last week, I had an opportunity to discuss several fields -- astronomy, oceanography, and the atmospheric and earth sciences -- which are characterized by a high dependence on instrumentation and research facilities. It is the case, however, that investigators in virtually every field of science and engineering which the Foundation supports are increasingly dependent upon research instrumentation and computers if they are to conduct leading-edge research in their disiplines. The quality and availability of instrumentation and computers to researchers can also have a major impact on their productivity and on the efficiency with which they can carry out their work. Let me give you two brief examples of what improvements in instrumentation can mean for a field of science.

Instrumentation and Research: CCD's and NMR's

We are all aware of how solid state devices have revolutionized communications and computing over the last 20 years. A much less widely known product of solid state electronics is the charge coupled detector array. These arrays of photosensitive diodes allow astronomers to detect, spectrally scan and map light sources in the universe hundreds of times fainter than those previously observable.

Prior to the use of these detectors, astronomers relied upon photographic exposures for making and recording their observations. Of every 1,000 photons that fall on a photographic plate, up to 30 may be recorded in the image. A charge coupled detector, in contrast, may record as many as 800. In addition to this major increase in sensitivity, the output of a detector is an electrical signal that is easily digitized for imaging and further computer processing. Thus the time-consuming conversion of photographic images to digital form, using analog to digital scanners, is no longer necessary. In addition, images obtained from optical telescopes can now be compared directly with those maps obtained by radio telescopes.

Once the concepts underlying these detectors were initially outlined and understood, much of their early development and testing was supported by the National Aeronautics and Space Administration as a part of its development of the space telescope. Today, virtually every major observatory has a charge coupled detector in use or being tested and major improvements are continually being made both in the devices and in their application in new instruments. Not only have these devices made new observations possible, but they have increased the efficiency of researchers and have brought radio and optical astronomy closer together. Since many individual astronomers now employ both observational techniques as a normal part of their work, we can expect new understandings of the basic nature of our universe to emerge.

Since all natural pheonomena are intrinsically related, the results of research in one field -- say physics -- can and do have unexpected and revolutionary impacts on work in other disciplines.

These interactions can be especially dramatic when they involve the development of an instrument.

A prime example of this is the phenomenon of nuclear magnetic resonance (NMR) investigated by the physicists Bloch at Stanford and Purcell at Harvard, both of whom received the Nobel Prize for thier work. Bloch and Purcell were working, independently, on an esoteric problem -- the behavior of substances in a magnetic field when they are irradiated by radio frequency waves. Using classical and quantum mechanics, they predicted and observed that water subjected to these conditions would absorb energy. Building on this basic insight, scientists realized that the absorption of energy was characteristic of the elements making up the molecule and its local environment. In the case of the original experiment, the absorbing element in the water molecule was hydrogen -- an element widely found in natural systems.

Soon, the phenomenon of nuclear magnetic resonance, originally studied for its own sake, was developed into a nuclear magnetic resonance spectrometer -- a tool for probing the nature of the molecules themselves. Without exaggeration, the application of NMR spectroscopy to problems in chemistry, biochemistry and molecular biology has had revolutionary impact in these fields.

Before the development of NMR scientists used X-ray diffraction to study the three dimensional structure of molecules. X-ray diffraction was, however, limited to molecules in the solid state. With NMR it

BECAME POSSIBLE FOR THE FIRST TIME TO STUDY THE SPATIAL STRUCTURE OF MOLECULES IN SOLUTION. PHYSIOLOGISTS, FOR EXAMPLE, COULD INVESTIGATE THE RELATIONSHIP OF THE STRUCTURE OF A MOLECULE IN SOLUTION -- THE BIOLOGICALLY IMPORTANT SITUATION. REACTIONS COULD BE MONITORED IN A CELL OR TISSUE UNDER NORMAL, ABNORMAL, OR DISEASED CONDITIONS. FOR EXAMPLE, THE SYNTHESIS OR DEGRADATION OF ADENOSINE TRIPHOSPHATE, THE SOURCE OF ENERGY IN MUSCLE ACTION, COULD BE FOLLOWED AND FOLLOWED NON-DESTRUCTIVELY AND NON-INVASIVELY. PREVIOUSLY, IT WAS NECESSARY TO DESTROY OR KILL THE TISSUE. BIOLOGISTS STUDIED REACTIONS IN THE INTACT LIVER, INTACT HEART MUSCLE, AND IN OTHER TISSUES AS THEY METABOLIZED.

MOREOVER, IT IS NOW ACTUALLY POSSIBLE TO MAP THE INTERIOR OF A TISSUE OR ORGAN USING NMR IMAGING IN A MANNER THAT IS ANALAGOUS TO THAT USED IN CAT-SCANNING. LIVING SYSTEMS CAN BE STUDIED DIRECTLY AND POTENTIALLY HARMLESSLY BOTH FOR SCIENTIFIC AND MEDICAL PURPOSES. THUS, AN EXOTIC PREDICTION BASED ON A COMPLEX THEORETICAL MODEL FAR REMOVED FROM THE REAL WORLD OF BIOLOGY AND MEDICINE DEVELOPED, THROUGH THE EFFORTS OF MANY PHYSICISTS, CHEMISTS, AND BIOLOGISTS, INTO AN IMPORTANT TOOL FOR ADVANCING THE UNDERSTANDING OF LIFE PROCESSES.

NATIONAL INVESTMENT IN RESEARCH INSTRUMENTATION

AS THESE TWO EXAMPLES DRAMATICALLY SUGGEST, AN INVESTMENT IN RESEARCH INSTRUMENTATION IS AN INVESTMENT THAT INCREASES BOTH THE QUALITY OF THE SCIENCE THAT CAN BE PURSUED AND THE PRODUCTIVITY AND

EFFICIENCY OF THE INVESTIGATOR. IN ADDITION, WHEN THIS EQUIPMENT IS LOCATED ON A UNIVERSITY OR COLLEGE CAMPUS IT CONTRIBUTES SIGNIFICANTLY TO THE TRAINING OF THE GRADUATE STUDENTS WHO WILL BECOME THE FUTURE SCIENTISTS AND ENGINEERS STAFFING OUR INDUSTRIAL, ACADEMIC, AND GOVERNMENTAL INSTITUTIONS. THUS, IF WE ARE TO REALIZE THE FULL POTENTIAL OF OUR NATION'S INVESTMENT IN RESEARCH AND IN GRADUATE EDUCATION, IT IS VITAL THAT WE MAINTAIN AND CONTINUALLY IMPROVE THE QUALITY AND AVAILABILITY OF ITS INSTRUMENTATION BASE.

IN THE PAST FEW YEARS, THERE HAS BEEN A GROWING REALIZATION THAT WE, AS A NATION ARE UNDERINVESTING IN STATE-OF-THE-ART INSTRUMENTATION AND FACILITIES IN ACADEMIC INSTITUTIONS. THOUGH THE EXACT MAGNITUDE OF THE PROBLEM CANNOT BE DETERMINED AT PRESENT, NUMEROUS INDICATORS ALL SEEM TO POINT IN THE SAME DIRECTION: THE PROBLEM IS LARGE AND INVOLVES MOST AREAS OF SCIENCE AND ENGINEERING AND MOST OF OUR MAJOR RESEARCH UNIVERSITIES.

A STUDY BY THE AMERICAN ASSOCIATION OF UNIVERSITIES IN 1981, FOR EXAMPLE, EXAMINED THE INSTRUMENTATION AND FACILITIES NEEDS OF SIX DISCIPLINES IN 15 LEADING UNIVERSITIES. OFFICIALS IN THESE INSTITUTIONS REPORTED THAT THEY WERE WERE FREQUENTLY UNABLE TO PROVIDE RESEARCHERS AND STUDENTS WITH ACCESS TO MODERN EQUIPMENT IN ONE OR MORE OF THESE FIELDS. IN GENERAL, THERE WAS A PATTERN OF PIECEMEAL AND UNECONOMICAL EFFORTS AT RENOVATION AND REPAIR OF EXISTING EQUIPMENT THAT RESULTED FROM INSUFFICIENT FUNDS. THESE UNIVERSITIES REPORTED THAT THEY WOULD HAVE TO SPEND ALMOST $800 MILLION OVER THREE YEARS JUST TO PROVIDE MODERN EQUIPMENT FOR THEIR EXISTING FACULTY.

Extrapolating from these numbers, the AAU study suggested that as much as $4.4 billion would be required over a 3-5 year period to fully upgrade instrumentation at the 100 leading academic research institutions.

More recently, at the urging of this Committee, the Foundation has begun to develop statistically reliable indicators of trends in the cost, condition, and utilization of research instrumentation in universities as a basis for projecting current and future needs. Questionnaires have been sent out to a stratified sample of 40 institutions from among the 160 largest performers of academic R&D. In phase one, information will be gathered on engineering, computer science, and the physical sciences. In the second phase, additional information will be collected on the biological, agricultural, and environmental sciences.

While the results from the first phase will not be available until later this year, the Foundation has already completed a pilot study in 38 institutions in four subfields -- organic chemistry, cell biology, solid state physics, and electrical engineering. This pilot study found that about one-fourth of the research equipment in the four fields combined was ten years old; one-fourth was five to nine years old; and one-half was less than five years old. In the next five years, researchers plan to replace one-fifth of ALL the equipment and 36 percent of that costing $50,000 or less. Sixty-five percent of the total equipment had been acquired partly or entirely with Federal funds.

In FY 1983, the Department of Defense announced a special $30 million program aimed at upgrading academic research instrumentation. In response to this announcement, they received over $600 million in proposals. This is still another indication of the potential magnitude and importance of the problem.

NSF Support of Instrumentation

The Foundation's programs support the purchase and operation of research instrumentation and associated facilities in one of several modes. The most general and common way is to provide a single investigator with the instrument he requires in connection with his peer-reviewed project. The equipment is most frequently off-the-shelf and averages about $15,000 to $18,000 per piece. More expensive, single instruments for multi-user, multi-group projects may be requested through special programs such as the Astronomical, Biological, Chemical, and Materials Research Instrumentation programs. Some of this equipment, such as the millimeter wave receivers in astronomy, is developed and some is off-the-shelf. The cost probably averages around $90,000 per piece.

Between FY 1978 and FY 1980, NSF established fourteen Regional Instrumentation Facilities intended to make costly instrumentation accessible to a large number of qualified users, including those at smaller institutions. The specialties of these facilities ranged from mass spectroscopy at the University of Nebraska and at Johns Hopkins

University, to NMR at Yale and the University of South Carolina and the University of Illinois.

Finally, the Foundation supports a limited number of large scale facilities such as Kitt Peak National Observatory, the academic oceanographic fleet, and the National Center for Atmospheric Research. My remarks before your Committee last week demonstrated the significance of such facilities for research in the astronomical and geophysical sciences.

The FY 1984 Budget Request addresses the problem of increased need for research instrumentation by placing a high priority on it in most of the Foundation's programs. It is estimated that support of research instrumentation for NSF as a whole will increase by about 61 percent between FY 1983 and FY 1984.

Each program addresses research instrumentation in a manner that is consistent with its particular requirements and needs. This permits maximum flexibility in attending to the equipment needs in each discipline as to size, cost, and mode of support. The highlights of their activities include:

o A new equipment program in engineering which will require matching funds from industry and the grantee university;

- An instrumentation program in computer research to provide support for the purchase of minicomputers by individual investigators;

- Partial support for the acquisition of a new sub-millimeter and an optical telescope costing in the $1 - $2 million range, as well as support for improved receivers and processing equipment;

- Expansion of support of research and equipment at the Cornell Electron Storage Ring, the Illinois electron accelerator, and the Indiana University Cyclotron; and

- Investment in geochemical instrumentation such as mass spectrometers, electron beam instruments, and geophysical detectors to upgrade and replace research equipment in the earth sciences supported originally by NASA and the DOD over a decade ago.

In FY 1982, the Foundation organized the Interagency Working Group on University Research Instrumentation with representatives from the Department of Defense, the Department of Health and Human Services, the Department of Energy, the Department of Agriculture, and the National Aeronautics and Space Administration. These agencies, which with NSF provide over 95 percent of Federal support of university research, are acquiring further data on the state of university equipment, are taking new initiatives within their research budgets to

PLACE GREATER EMPHASIS ON INSTRUMENTATION, AND ARE MAKING FEDERAL LABS MORE ACCESSIBLE TO UNIVERSITY RESEARCHERS.

RESPONSES BY UNIVERSITIES AND THE PRIVATE SECTOR

IT IS ALSO CLEAR TO US AT THE FOUNDATION THAT MANY UNIVERSITIES HAVE BEGUN TO ACCEPT RESPONSIBILITY FOR IMPROVING THEIR MANAGEMENT OF INSTRUMENTATION AND ARE ABOUT TO EMBARK ON A MAJOR EDUCATION EFFORT TO ENCOURAGE NEW FINANCING ARRANGEMENTS, EQUIPMENT SHARING, AND MORE RESPONSIVE UNIVERSITY REGULATIONS AND POLICIES. A REVISION OF OMB CIRCULAR A-21 HAS HELPED. IN THE PAST, INTEREST WAS NOT AN ALLOWABLE COST TO BE INCLUDED IN UNIVERSITY OVERHEAD. WITH THIS REVISION, INTEREST ON LOANS FOR PURCHASE OF PIECES OF RESEARCH EQUIPMENT COSTING $10,000 OR MORE IS ALLOWABLE.

THE ECONOMIC RECOVERY TAX ACT OF 1981 PROVIDED INCENTIVES FOR MANUFACTURERS OF SCIENTIFIC INSTRUMENTS TO CONTRIBUTE RESEARCH APPARATUS TO INSTITUTIONS OF HIGHER EDUCATION. THE LAW PERMITS A CORPORATION MAKING A QUALIFIED EQUIPMENT DONATION TO TAKE UP TO TWICE THE COST OF MANUFACTURING AS A TAX DEDUCTION. THE EFFECTIVE IMPACT OF THIS PROVISION ON THE BEHAVIOR OF EQUIPMENT MANUFACTURERS IS STILL UNCLEAR BECAUSE THE TAX PROVISIONS ARE COMPLEX AND BECAUSE THEY ARE JUST ONE SET OF MANY FACTORS WHICH AFFECT THE TAX POSITION OF FIRMS DONATING EQUIPMENT TO ACADEMIC INSTITUTIONS.

THE FOUNDATION HAS EXPERIMENTED WITH ENCOURAGING PRIVATE INSTRUMENT MANUFACTURERS TO MAKE CONTRIBUTIONS OF SCIENTIFIC

INSTRUMENTATION TO UNIVERSITIES. ONE EFFORT RESULTED IN GIFTS OF COMPUTERS TO COLLEGES AND UNIVERSITIES TO FACILITATE THE DEVELOPMENT OF SPECIAL COURSEWARE IN PRECOLLEGE AND UNDERGRADUATE EDUCATION. IN ANOTHER, MAJOR COMPUTER MANUFACTURERS GAVE NSF GRANTEES SUBSTANTIAL DISCOUNTS ON COMPUTERS TO BE USED IN RESEARCH IN MATHEMATICS.

SENSITIVE TO POSSIBLE QUESTIONS CONCERNING THE FEDERAL ROLE IN ARRANGEMENTS OF THIS SORT, THE NATIONAL SCIENCE BOARD AT ITS OCTOBER, 1982, MEETING ESTABLISHED A POLICY ENCOURAGING SUCH ARRANGEMENTS AND DIRECTING THE FOUNDATION TO "AVOID ACTIONS THAT WOULD COMPROMISE THE INTEGRITY OF THE NSF; AVOID FAVORING OR APPEARING TO FAVOR ONE MANUFACTURER OVER ANOTHER; AND AVOID INAPPROPRIATE EXPLOITATION OF NSF'S REPUTATION." MORE RECENTLY THE BOARD ALSO DEALT WITH THE QUESTION OF POSSIBLE COMMERCIAL USE OF NSF SUPPORTED INSTRUMENTATION IN A STATEMENT ADOPTED IN JANUARY, 1983, EMPHASIZING, IN PART, THAT ". . . IT IS CONTRARY TO NSF'S INTENT FOR GRANTEES TO USE NSF-SUPPORTED RESEARCH INSTRUMENTATION OR FACILITIES TO PROVIDE SERVICES FOR A FEE IN DIRECT COMPETITION WITH PRIVATE COMPANIES THAT PROVIDE EQUIVALENT SERVICES." THE FOUNDATION IS CURRENTLY REVIEWING A NOTICE WHICH WILL BE SENT TO UNIVERSITIES AND COLLEGES LATER THIS YEAR OUTLINING THE GUIDELINES FOR THE USE AND OPERATION OF NSF-SPONSORED RESEARCH INSTRUMENTATION AND FACILITIES.

CONCLUDING REMARKS

MR. CHAIRMAN, I FEEL CERTAIN THAT YOU AND THE OTHER MEMBERS OF YOUR COMMITTEE SHARE MY VIEWS ON THE CRITICAL IMPORTANCE OF

INSTRUMENTATION FOR MAINTAINING THE QUALITY OF OUR SCIENTIFIC ENTERPRISE AND FOR STRENGTHENING OUR TRAINING OF FUTURE SCIENTISTS AND ENGINEERS. AN INVESTMENT IN RESEARCH INSTRUMENTATION IS AN INVESTMENT IN QUALITY GRADUATE EDUCATION AS WELL AS QUALITY SCIENCE AND ENGINEERING.

I BELIEVE THAT THE FOUNDATION'S FY 1984 PROGRAM WILL TAKE A FIRST IMPORTANT STEP TOWARDS UPGRADING THE PRESENT QUALITY OF AVAILABLE INSTRUMENTATION IN THE NATION'S COLLEGES AND UNIVERSITIES. I ALSO BELIEVE THAT THE LEADERSHIP ROLE WHICH THE FOUNDATION HAS PLAYED AND WILL CONTINUE TO PLAY IN URGING OTHER FEDERAL AGENCIES, THE PRIVATE SECTOR, AND UNIVERSITIES THEMSELVES IS OF GREAT IMPORTANCE IF WE ARE TO CONTINUE THIS ADVANCE.

Mr. **Walgren**. Thank you very much, Dr. Knapp.

The figure of 65 percent of equipment being acquired with Federal or partly Federal funds rings a lot of bells, which I guess just again emphasizes the magnitude of the problem. I remember I went to one of my universities not too long ago, the engineering laboratory, and it was literally all World War II distribution from the defense effort, except for two computers that were charitably given by a Japanese company, and they had little plaques on the wall. However, it was just amazing to see the Federal base in that laboratory, from my perspective.

We are very interested in NSF's trying to grapple with this problem. You indicate that you are going to be spending a certain amount—a 61-percent increase in the budget in 1984 over 1983—in research.

Dr. **Knapp**. That is correct.

Mr. **Walgren**. This committee in the past has, with a rather blunt instrument, promulgated the thought that perhaps 10 percent of research money should be spent on instrumentation. How do NSF's operations measure against that kind of a direction?

Dr. **Knapp**. It depends on which of the Foundations's directorates you are discussing. In the MPS directorate, for fiscal year 1984 about 20 percent of the budget will be for instrumentation—with this 61-percent increase. In the other directorates, the percentage increase is somewhat less. I would say that 10 percent is probably slightly low compared to what NSF will really do in fiscal year 1984.

Mr. **Walgren**. How can we be satisfied that we can really track those dollars into instrumentation? Is your administrative system at NSF set up in such a way that you can really say point blank that *x* dollars of the moneys that you commit are in fact directed towards instrumentation?

Dr. **Knapp**. There are three different ways in which NSF supports instrumentation. One is in the research grants themselves;

the second is with these special instrumentation programs; and the third is the support of large facilities used for research in the various disciplines.

In the latter two, it is easy to track money spent for instrumentation, and about 60 percent of the total instrumentation budget is in the latter two categories. The large facilities—we certainly know they are there—and they are instrumentation. In the research instrumentation centers and the special instrumentation programs, the instrumentation is also clearly documented.

Where there may be a question as to whether the money has really been spent for instrumentation is the area of instrumentation supported with research grants. In that area, we are alerting NSF program managers to verify during site visits that the instrumentation is up to date and meets the description provided in the research proposal.

However, there is no specific way that the Foundation can require the reporting of the purchase of instrumentation on a grant after the grant is awarded to the university. Of course, the title to the equipment rests with the university that gets the grant; it is not government equipment.

We can be quite certain, however, that the research done with the funds provided by NSF does use the equipment requested in the grant. It has to do that in order to be competitive.

Mr. **Walgren**. You mentioned these regional instrumentation efforts through NSF, regional instrumentation facilities. How do they work?

Dr. **Knapp**. Some instrumentation necessary for the conduct of certain kinds of research is located all in one place, for example, a university campus. Investigators from all of the universities in that area come to that facility and use the instrumentation for the experiments that they wish to do.

That arrangement is good for some kinds of research; it is inappropriate for others. It is certainly clear that all instrumentation could not be handled that way. However, it is successful for some kinds of instrumentation, and it is used widely in some fields.

Mr. **Walgren**. Thank you very much.

Mr. Gregg.

Mr. **Gregg**. You have increased your budget by almost $90 million over 1982 actual?

Dr. **Knapp**. For instrumentation?

Mr. **Gregg**. Right.

Dr. **Knapp**. Yes.

Mr. **Gregg**. That is a considerable increase, and I congratulate you for it. Do you think it meets all your needs?

Dr. **Knapp**. The solution to the instrumentation problem will be a multiyear program within the Foundation emphasizing instrumentation for many years in order to satisfy the need. The need is really very great. The number quoted in my testimony—an $800 million shortfall in 15 major research universities—has been fairly well documented. The larger number for all university research is not so well documented, but it must be in the billion dollar range, perhaps, in the multibillion dollar range.

Therefore, clearly an $80 million increase in instrumentation funding does not solve the problem in a year or several years. However, there are other sources of funding for instrumentation: the DOD has a program; the DOE also funds instrumentation in universities. Taken as a whole, with all of the agencies funding instrumentation at an enhanced rate for the next few years, we will be able to make a fair improvement in the problem the universities are facing today.

Mr. GREGG. In arriving at this funding increase, did you have to adjust any of the other directorates?

Dr. KNAPP. All of the NSF research directorates are participating in the increased funding for instrumentation.

Mr. GREGG. Where did the increase come from? Is it an additional, add-on, or is it a transfer from people?

Dr. KNAPP. Instrumentation makes up a major part of the increased funding requested for fiscal year 1984. We have not taken funds from the conduct of science in order to get the increase in instrumentation; we have just emphasized instrumentation with the increase in funding.

Mr. GREGG. Thank you.

Mr. WALGREN. Thank you, Mr. Gregg.

Mr. Bateman.

Mr. BATEMAN. I have no questions, Mr. Chairman.

Mr. WALGREN. Mr. Skeen.

Mr. SKEEN. Dr. Knapp, you make mention in the report of the Foundation's own research program that it would require matching funding from industry. What kind of reception are you getting? You alluded to it, but as a specific response can you give me any idea of how well received the program is, how much progress you are making in matched funding?

Dr. KNAPP. I can say something about what has happened in the computer equipment business, where we have had quite a bit of success in obtaining donations and discounts from some computer manufacturers.

Mr. SKEEN. Either equipment or funding, you get a little of both or get offers of both.

Dr. KNAPP. Yes. I don't know how the idea of matching funds for equipment at these higher dollar values will be received, but at the level that NSF has been operating, I see no great problem in getting matching funds for NSF instrumentation programs.

Mr. SKEEN. It doesn't cause the Foundation any ethical problems?

Dr. KNAPP. We must be careful there. We are trying to walk a line that does not give one manufacturer an edge in the market over another manufacturer. NSF, of course, is only a matchmaker in this effort. NSF puts universities in touch with companies, and they make whatever arrangements seem best for the universities. NSF is not involved in any contractual arrangements, but still we must be careful that the process is completely open, without favor for one manufacturer over another.

We have worried a great deal about that. The Board's guidance helps assure that the Foundation has been careful to avoid any conflicts that could cause problems.

Mr. SKEEN. Well, we here on the Hill think there is probably—or a lot of us do, some of us don't—and I don't envy your position as being a marriage broker or a counselor. Either one, Dr. Knapp, in this case would be kind of difficult. However, I would think too that we would like to encourage this kind of thing. In certain situations that we are familiar with in this part of the country, there is this willingness to have this kind of participation and cooperation.

It's very difficult, though, who makes the first approach in this thing. I would think the National Science Foundation would have a very difficult problem deciding who is it that brings up the subject, or who do you approach in a cooperative sense. I don't know; is industry itself willing to make the initial approach in these suggestions for universities or other institutions, in matching funds or gifts of equipment and so forth?

Dr. KNAPP. In the case of the computer equipment that I alluded to, I understand the Foundation was makings grants for computer equipment in several universities, and a manufacturer came forward with a proposal. If items could be lumped, then the universities could have such-and-such equipment with a large discount; and it was accepted.

Mr. SKEEN. Is it a widespread practice now, or is it increasing, or——

Dr. KNAPP. I think it is fairly widespread.

Mr. SKEEN. Thank you very much, Dr. Knapp.

Thank you very much, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Skeen.

Mr. Brown.

Mr. BROWN. Dr. Knapp, does the Foundation have any plans for supporting any new earth-based optical telescope developments in the next few years?

Dr. KNAPP. The Astronomy Division of the Foundation is requesting funds to study technology that could lead towards a large, earth-based optical telescope. The new technology is not defined, but, there are ideas on how to proceed with the development of the technology for such a telescope. No design is being developed. Studies underway all looking at possible ways of making large mirrors without requiring massive systems to support them.

Mr. BROWN. The University of California people have not spoken to you about what they are proposing to do? I think they have an instrument somewhat like this in mind, in the conceptual stage.

Dr. KNAPP. I am not aware of it. No one from the University of California has come to see me specifically. I am certain that they are talking with NSF staff in the Astronomy Division.

Mr. BROWN. Going on to another subject—and I have not read your statement yet, and I apologize for that—could you comment on the status of the NSF computer science network, what they call CSNET? I am interested in whether or not that network is intended to provide broader scientific access to supercomputers. Every time I turn around there seems to be a new generation of computers and new networks developing, and I am kind of wondering what the role is that NSF is playing in that development.

Dr. KNAPP. That is an extremely complicated topic. The CSNET itself is a network connecting computer science departments in universities funded by NSF around the country. As a network, it is inadequate to serve for access to supercomputing. It is relatively slow. It is used for transmitting data and messages, but it is not adequate for high data rates required in supercomputing systems, such as can be transmitted on ARPANET or the magnetic fusion network developed in the Department of Energy.

ARPANET is a network supported by the DOD. It is adequate for access to large-scale scientific computing; in fact, this network is available on many university campuses and perhaps could be expanded and incorporated with CSNET to make a network for major computer access by researchers on university campuses.

There is the future possibility that commercial networks will be developed with adequate capacity so that universities can be connected to large-scale computing facilities remote from their campuses. However, commercial networking must be looked at carefully. We must understand exactly what we are getting involved with before we would use a commercial network for this purpose.

The Foundation has formed a committee among the assistant directors to look at the problem of computer access for NSF grantees. We want to understand an optimum direction to proceed in achieving access to major computers for the grantees. This will be a major topic of consideration at the Board meeting in May.

I personally believe that access to large computers by scientists in the universities is extremely important. It must be a multiagency, program—not just the NSF—in order to coordinate all of these efforts and get the most access for the minimum expenditure of funds.

Mr. **Brown**. Wasn't that one of the recommendations of the conference on large-scale computing which you sponsored with the DOD a year or so ago? Oh, you weren't here then, yes.

Dr. **Knapp**. I wasn't here, but I think that is correct.

Mr. **Brown**. I was out at NCAR—I may have mentioned it to you—last month, and I observed the Cray machine, and I think I was told that they were developing connections with some of the adjoining western universities with that machine, some sort of a network or access. You have mentioned, I think, the fusion use. Don't Los Alamos and Livermore both have Cray machines?

Dr. **Knapp**. Yes.

Mr. **Brown**. Are they interconnected?

Dr. **Knapp**. They are not interconnected, but there is a Livermore machine, perhaps two machines, in the FUSION NET which, for example, researchers at Princeton University use almost continuously.

Mr. **Brown**. Are they linked by microwave or satellite or——

Dr. **Knapp**. The FUSION NET is linked by satellite; the ARPANET by telephone line and probably microwaves. I am not certain the way it works, but the lines are not just typical, dial telephone lines. Such lines are much too slow for this purpose.

Mr. **Brown**. Do you ever visualize in your mind's eye some utopian network which is interconnected by satellite and has all kinds of public service connection capabilities?

Dr. **Knapp**. I am not sure you can do everything for everybody in one system, but if this technology continues to evolve, certainly scientific computing around the country will be interconnected in a general way.

Mr. **Brown**. Is there a difference in the interconnections required here and the interconnections that would be required in this contract that I understand the Air Force let to interconnect all their computers on a global basis just a month or two ago?

Dr. **Knapp**. I don't know the details of the Air Force contract.

Mr. **Brown**. Thank you very much.

Mr. **Walgren**. Thank you, Mr. Brown.

Do we know how much of the equipment and instrumentation effort goes into computers as opposed to other kinds of equipment?

Dr. **Knapp**. I don't, but we could certainly supply the information for the record.

[The material follows:]

Computer Equipment Funding

NSF funding for computer equipment in the four research directorates (AAEO, BBS, ENG, MPS) is estimated to be $14.7 million in Fiscal Year 1983 and $25.8 million for Fiscal Year 1984. This represents 13.1 percent of the total equipment and instrumentation in Fiscal Year 1983 and 14.3 percent in Fiscal Year 1984.

Mr. **Walgren**. I guess it is obvious that networks are possibly very helpful in terms of reducing cost, and yet we are only to the stage of having a committee at this point in NSF to evaluate what networking in terms of access ought to be. Is that your testimony?

Dr. **Knapp**. Certain kinds of computing have dominated the field during the past few years. Relatively smaller computers have been involved. In fact, for most scientific calculations, computers that are compatible with a university campus are really needed. Only in special-purpose cases, such as Mr. Wilson discussed with the committee a couple of weeks ago, are supercomputers really necessary and access to the network is really required.

It is a fairly complicated problem—getting the right kind of computing for the right number of people on all the campuses. It will take a while to understand all the ramifications of an optimum system for the country. If it is possible to have a computer on campus adequate to the needs of investigators who are doing the research there, and if the computer would be completely utilized, then I think it is clearly preferable to have the computer on the campus rather than remotely located.

Mr. **Walgren**. With respect to being completely utilized, I understand that there is this process where pieces of equipment might be available if we were allowing user charges as cost elements in a research proposal, where a larger system could be put in place and, without NSF money, built into the structure of whatever entity was putting it there, but then the financing base to carry that instrument would be made up of various user charges. Do we have those user charges as legitimate expenses at this point?

Dr. **Knapp**. I understand that those are legitimate expenses.

Mr. **Walgren**. Just one other thought: It is my understanding that there is this National Technical Information Service, and it tries to be a network for certain information but NSF does not contribute to that. Is that correct?

Dr. **Knapp**. I'm sorry, I don't know the details.

Mr. **Walgren**. Well, maybe we could ask somebody to give us a view of that. The idea is that supposedly the NSF is the only Federal agency which does not provide information with respect to research findings to this technical information service, and if that is the case, we ought to understand why we are withholding and what we are withholding.

Dr. **Knapp**. I'm sorry. I don't know any detail at all.

[The material follows:]

During the years that the Smithsonian Science Information Exchange served as the clearinghouse for research in progress, NSF furnished hard-copy summaries (Form 4) of all grants to the Exchange on a routine basis. However, when NTIS assumed this responsibility and required the input in the form of computer readable, indexed abstracts of current research projects, NSF was forced to reconsider its participation. After reviewing the substantial additional costs of the work required to provide the information and in the absence of compelling evidence that it would be used extensively by the scientific community, NSF decided not to participate in the data collection in its current form. NSF does, however, arrange for the dissemination through NTIS of research results in applied and policy related research where the traditional means of dissemination used in discipline-oriented basic research may not be adequate.

Mr. **Walgren**. OK. This Circular A-21—and this is an area that I don't know very much about at all—you say it was revised. I am remembering that a certain amount of overhead was asked to be shouldered by the institutions, at least in the medical area, by this administration just as a cost-cutting effort in research. They were going to simply strike from the grants 10 percent of the administrative costs.

That seems to run counter to your reference to Circular A-21, where you are allowing greater overhead costs to be covered in your grant, essentially. Is that an area of any controversy presently in NSF?

Dr. **Knapp**. No, it has not come to my attention since I have been Director that any cutting of the overhead or indirect costs is being contemplated for NSF grants.

Mr. **Walgren**. Mr. Gregg.

Mr. **Gregg**. Dr. Knapp, you are aware, of course, that H.R. 1310 passed the House and that in that there was the matching grant proposal for the $100 million fund to be set up under the Fuqua proposal. Can you advise us as to how you are contemplating handling that, assuming it proceeds?

Dr. **Knapp**. The administration is studying its position with respect to H.R. 1310, and I probably should not comment directly. We are studying the provisions affecting NSF in portions of that bill. We feel now that the various provisions are such that NSF would have funding for a reasonable program in support of science and mathematics education.

Mr. **Gregg**. I guess you are saying, essentially, that you don't want to get into it until it passes and the administration has accepted it?

Dr. **Knapp**. There are many players in the act.

Mr. **Gregg**. We will stand by, then, waiting for that to be further sugared off so that we could get—I think it would be good if NSF could give a sense of how you are going to handle this.

Mr. **Walgren**. Further sugared off? Is that a local——

Mr. **Gregg**. We're getting into the spring now.

Mr. **Walgren**. Mr. Gregg is from New Hampshire.

Mr. **Gregg**. I would be interested in whether you plan to set up a different directorate or whether you intend to——

Dr. **Knapp.** I commented on that question at a hearing of this subcommittee recently. I said that depending on the size and complexity of the program NSF, would have to put forward, I would have to decide about a separate directorate for education. I would like to wait until that time to comment on the plans. It is clear that if NSF has a large program, it must have an appropriate organization to manage the program.

Mr. **Gregg.** Very good. Thank you.

Mr. **Walgren.** Mr. MacKay, any thoughts or questions?

Mr. **MacKay.** No, Mr. Chairman.

Mr. **Walgren.** Mr. Sensenbrenner.

Mr. **Sensenbrenner.** No questions.

Mr. **Walgren.** OK. Let me ask one final one, if I could, and that is, it is our understanding that the Department of Energy is proposing a $180 million effort in a materials laboratory over a period of 5 years. The question arises, how does NSF relate to that, inasmuch as a large part of the physical science effort is related to materials? Why would that laboratory go into DOE, as opposed to being run by NSF, and what was our input to that decision from NSF's standpoint?

Dr. **Knapp.** Yes, NSF has a Materials Science Division and materials science is also in other divisions, such as the Chemistry Division. NSF supports a lot of work in materials, but the Department of Energy also does a great deal of work in materials. The Department has a Materials Research Division with a large budget, probably larger than the NSF's budget in materials research.

NSF funds only a fraction of the materials research conducted in the country; it is and has been a Department of Energy field of science. The Department is only expanding its effort in this field.

As for NSF's input into DOE's proposed program, I feel myself that materials science is an extremely fruitful and active area of science, something that could easily take expansion. It is an important program and an area of science that will return great dividends to this country.

As for detailed plans to fund this laboratory, NSF has not been involved in the planning. However, I do not think it will affect adversely NSF grantees in Foundation-supported materials science laboratories. In fact, as I say, having more effort in materials science is a positive step for the country to take.

Mr. **Walgren.** Can I ask how we would be coordinated in general with other research efforts of the Government? If we have not been involved with the direction and the thrust of that DOE laboratory, that then raises a general question of the state of coordination of effort that we are making on many levels.

Dr. **Knapp.** I can speak specifically about the two fields of science in which I have experience as a scientist. I think the coordination between the Department of Energy and the National Science Foundation in both high energy physics and in nuclear physics is excellent. We have joint committees with members from both DOE and NSF. We try to plan joint programs in which NSF grantees use Department of Energy facilities, and vice versa.

Therefore, in the fields that I am aware of, we have excellent coordination. Materials science is a field with which I am less familiar as a scientist. I do not know what the mechanisms are in that field, but I would think, as materials science needs the size of equipment that requires national centers such as the synchrotron light source at the Brookhaven Laboratory and neutron scattering facilities for solid-state physics studies at Los Alamos, it is important that similar committee structures be set up so that we do have close coordination of the programs.

Mr. **Walgren**. Maybe we could leave the record open at this point for some kind of submission that the Agency might like to make, which would assure us that from a management standpoint we are in direct pursuit of that kind of coordination that you certainly recognize, and more, as important.

Dr. **Knapp**. We will be glad to do so.

[The material follows:]

Coordination of NSF Programs With Other Federal Efforts

Mathematical and Physical Sciences

Mathematics -- Since NSF accounts for virtually all Federal support for core mathematics, the Foundation has a unique responsibility in this area. Formal coordination of the Federal effort is accomplished through an interagency group called ICEMAP (Interagency Committee for Extramural Mathematics Programs), which meets once a year to exchange list of grants and budget data. Informal interactions among NSF program managers and their Federal counterparts is continuous throughout the year.

Computer Research -- Interagency coordination is effected by an informal coordinating committee, by exchange of proposal and action lists and by person-to-person contacts. Particularly close coordination is maintained with DOD, DOE, NASA, and NIH in the initiative to provide increased long-range support for experimental computer science.

Physics -- Coordination with other government agencies is achieved through the High Energy Physics Advisory Panel of DOE, the joint NSF/DOE Nuclear Science Advisory Committee, and Interagency Committees on Atomic and Molecular Physics and on Plasma Physics involving NSF, DOD, and DOE.

Chemistry -- Coordination is accomplished through the Federal Interagency Chemistry Representatives Group, and the Interagency Coordinating Group in Laser Development and Applications. Individual NSF program directors interact regularly with their counterparts in other agencies, mainly DOE, NIH, and DOD to exchange information, discuss problems, and coordinate efforts.

Materials Research -- Interagency coordination occurs at several administrative levels which include the Committee on Materials of the Federal Coordinating Council for Science, Engineering and Technology, the Department of Defense Apportionment Reviews and informal program reviews. NSF has been instrumental in establishing and operating the Interagency Materials Group.

Engineering

Electrical Computer and Systems Engineering -- NSF program directors are in constant communication with research managers in associated areas in other agencies, not only those supporting basic research but also those in applied research and development. For example, electronics research is coordinated with related programs in the Office of Naval Research, the Air Force Office of Scientific Research, the Army Research Office, the Department of Defense Advanced Research Projects Agency, NASA, NBS and NIH through an ad-hoc interagency coordination committee. Systems research is coordinated with corresponding efforts in the Department of Energy, Department of Transportation, and the Department of Defense through common participation in technical society workshops and through informal meetings. Plasma and laser research is coordinated with the activities of DOE. Bioengineering staff members are participants in an Interagency Committee on the Biological Effects of Non-Ionizing Electromagnetic Radiation.

Chemical and Process Engineering -- Program directors in this area are also in frequent contact with Federal agencies having existing or potential interfaces with their programs. Examples include liaisons with the Department of Energy on fluidized bed technology, biomass utilization, catalysis, combustion, and nucleonics; with the U.S. Bureau of Mines on extractive metallurgy and particulate separation; with the National Bureau of Standards on thermodynamics and transport properties; with the Environmental Protection Agency on electrostatic precipitation; and with the Department of Defense on catalysis, plasma chemistry and arc technology. NSF staff also maintains active liaison with interagency and independent groups such as the Interagency Advanced Power Group, the International Fine Particle Research Institute, the American Chemical Society/Petroleum Research Fund, and the Task Force for Cooperative Advances in Chemical Science and Technology.

Civil and Environmental Engineering -- Coordination efforts by the Water Resources Engineering staff involve direct contact with the Office of Water Research and Technology in the Department of Interior and with the Environmental Protection Agency. Mission related structural mechanics research is carried out by the Office of Naval Research, Army Research Office in Durham, N.C., the Air Force Office of Scientific Research, and NASA. Through regular contacts, NSF ensures that its research program is properly related to the activities of these agencies. NSF program officers in Geotechnical Engineering are in regular contact with the U.S. Geological Survey and the Department of Energy. The National Earthquake Hazards Reduction Program, developed by the Executive Office of the President, has designated NSF as the lead agency for research on earthquake engineering. NSF is an active member of several research coordination groups, such as the Interagency Discussion Group on Disaster Mitigation. These groups meet regularly to consider recent developments in the field, current programs, and future activities in both the public and private sectors.

Mechanical Engineering and Applied Mechanics -- NSF program officers maintain contacts with their counterparts in other Federal agencies to exchange information and avoid unnecessary duplication. Principal agencies are the Department of Defense and the Department of Energy. Regular meetings take place with officers of the Office of Naval Research, Naval Research Laboratory, the David W. Taylor Naval Ship Research and Development Center, the Langley and Lewis Facilities of NASA, and the Army Research Office in Durham, N.C.

Biological, Behavioral, and Social Sciences

Physiology, Cellular and Molecular Biology -- Coordination with the research support activities of other Federal agencies is maintained through a variety of formal and informal mechanisms. Program Officers attend study section and Council meetings at the National Institutes of Health (NIH) as observers. Similarly, NIH officials often attend NSF advisory committee and subcommittee meetings and provide information about the NIH plans to fund proposals. These steps enable each agency to monitor specific research proposals and avoid duplication of effort. NSF staff members also serve as liaison representatives of a variety of advisory and interagency committees. The NSF-initiated Interagency Committee for Plant Sciences continues to bring together, periodically, representatives from the Department of Agriculture, National Institutes of Health, Department of Energy, National Aeronautical and Space Administration, Food and Drug Administration, Environmental Protection Agency, the Smithsonian Institution, and the National Academy of Sciences. Where appropriate, the program participates in joint support of research with other Federal agencies.

Biotic Systems and Resources — The Foundation provides essentially all of the Federal support for basic research in systematic biology, non-human population biology and ecology. Other Federal agencies, such as the Department of Agriculture, Interior, Energy and the EPA, support applied environmental research relevant to their missions. Many of these activities build upon the results of basic research. Coordination takes place through interagency committees and task forces in connection with problems of tropical deforestation, loss of genetic diversity, acid rain, global carbon dioxide, integrated pest management, and development of natural areas and biosphere reserves as research sites.

Behavioral and Neural Sciences — NSF provides the essential core support of projects that are not explicitly related to problems of health and disease. There are extensive formal and informal interactions between the Foundation's program staff and their counterparts in the National Institutes of Health, the Alcohol, Drug Abuse, and Mental Health Administration, the National Endowment for the Humanities, the National Institute of Education, the Office of Naval Research, and other agencies. When proposals are submitted to another Federal agency, each proposal to be recommended for award by NSF is reviewed to assure that duplicate support will not occur.

Social and Economic Sciences — Coordination is maintained with scientists and research administrators in other agencies, such as the National Institute for Child Health and Human Development, the National Institute of Mental Health, the Bureau of the Census, the Bureau of Economic Analysis, parts of the Departments of Treasury, Justice, Labor, Housing and Urban Development, the Federal Reserve Board, and the Council of Economic Advisors.

Information Science and Technology — Coordination with allied programs and other agencies is effected through reciprocal review and joint support of proposals, and participation in advisory committee meetings and scientific seminars. This program is the only source of Federal support for basic research over the full spectrum of information science and technology. Modest levels of support are provided by the National Library of Medicine, the Defense Advanced Research Projects Agency, and the Office of Naval Research for work directly related to their missions. NSF staff participates in working groups of the Federal Coordinating Council for Science, Engineering, and Technology of the Office of Science and Technology Policy, and maintains close relations with the National Telecommunications and Information Agency and the National Academy of Sciences Board on Telecommunications-Computer Applications.

Astronomical, Atmospheric, Earth, and Ocean Sciences

Astronomy — The Foundation has lead agency responsibility for the support of U.S. ground-based astronomy. Over two-thirds of Federal support for this part of the field comes from NSF through research grants to universities and contracts for the operation of the National Astronomy Centers. The other agency which provides significant support is the National Aeronautics and Space Administration (NASA). Coordination among agencies is standard practice at all management levels. Representatives from NSF, NASA, and other agencies with astronomers in Washington participate in meetings of the Government Astronomers' Round Table, an informal group whose members are involved in funding U.S. ground-based and space astronomy. NSF cooperates with NASA in several areas. Both agencies are sharing in the costs of supporting visitor use of the NASA infrared telescope in Hawaii. The two are in close contact on new technological developments such as solid state light detectors and minicomputers. The International Ultraviolet Explorer and other satellites are utilized by many NSF grantees in the course of their investigations. Sacramento Peak Observatory and Kitt Peak National Observatory staff collaborated closely with other scientists in space solar programs which were funded by NASA, such as the Solar Maximum Mission, Spacelab, and the International Solar Polar Mission.

Atmospheric Sciences — Atmospheric research support is coordinated through a number of mechanisms. A major coordinating mechanism for research is the Subcommittee for Atmospheric Research of the Committee on Atmosphere and Oceans (CAO). CAO is a committee of the Federal Coordinating Council on Science, Engineering, and Technology. In addition to this coordination, the National Center for Atmospheric Research and other NSF atmospheric science programs receive advice from committees of the NAS/NRC such as the Committee on Atmospheric Sciences, the Climate Research Board, the Geophysics Research Board, and the Ocean Science Board.

Earth Sciences — NSF's coordination of Earth Sciences with other agencies is partly formal, with program staff participating in interagency committees or discussion groups, such as the Interagency Geophysics Discussion Group, and partly informal through personal contacts. The staff of the Earth Sciences program has been active in committees that deal with earthquakes, geophysics, continental drilling, and mineral deposits.

Ocean Sciences -- Federal funding for ocean research is coordinated through the Committee on Atmosphere and Oceans, with advice from the National Advisory Committee on Oceans and Atmosphere and the National Academy of Sciences. The University-National Oceanographic Laboratory System (UNOLS) supported by NSF, ONR, and other agencies, provides a mechanism for efficient use and maintenance of the academic oceanographic research fleet. Coordination is also provided by informal contacts between NSF staff and their counterparts in other Federal agencies.

Ocean Drilling — The National Science Foundation coordinates support of the Ocean Drilling Programs with the work of other agencies through participation on interagency committees, and direct contact between NSF program managers and their counterparts in the USGS, the DOE, and other agencies.

Mr. **Walgren**. Mr. MacKay.

Mr. **MacKay**. Mr. Chairman, this question is along that same line.

Dr. Knapp, I am new on the committee and I am operating with some minimal knowledge and a great deal of presupposition. I had presupposed that NSF had as one of its primary roles the task of seeing to it that research went forward on a broad base. In other words, if there was an area where instrumentation or other resources were not flowing through other grant sources, you were one who had that responsibility, the National Science Board and your agency.

Now is that a proper assumption? If you do not, who does?

Dr. **Knapp**. The National Science Board and National Science Foundation do monitor the state of science, and we do comment about areas we feel need support. However, NSF has no function to plan other agencies' programs. It has its own program. NSF tries to act as a balance wheel. If it sees an area that needs support NSF can try to strengthen it with its own programs, but the Foundation does not presume to tell other departments of the Government where they should spend their money.

In areas where there is multiple funding—I think multiple funding of certain kinds of science is valuable to this country because it gives scientists more than one try at their best idea—NSF tries to bring real problems to proper attention. The Foundation attempts through joint committees to obtain balance and thorough discussion. A jointly felt need is filled by the agencies getting together and working together.

This type of coordination is important in areas as they become funded by multiple sources or as problems develop.

Mr. **MacKay**. Therefore, if the Department of Defense, for instance, was funding research in an area, you would feel that you could perhaps back off in that area and go into other areas that were being, perhaps, neglected because they did not fit into some agency's mission?

Dr. **Knapp**. NSF's first responsibility is to fund the basic sciences that do not necessarily fit into some agency's mission. NSF would not necessarily back off so long as it had good programs, but the Foundation would certainly try to make sure that the science was being covered—for the country's well-being.

Mr. **MacKay**. In the instrumentation that you will fund, I would assume other agencies' budgets may also fund instrumentation, as you were suggesting with DOE.

Dr. **Knapp**. That is correct.

Mr. **MacKay**. You would also take that into account.

What I am worried about is, I would hate to see the research effort in this country being driven, say, by the defense buildup, and I have heard some obviously biased people say they think that is happening.

Dr. **Knapp**. NSF's programs are almost entirely investigator-initiated and peer-reviewed, so NSF's budget increase—a major increase for basic science—is certainly not driven by a particular mission. It is driven by the feeling of the scientists themselves that they are investigating areas containing new knowledge with useful potential. It is driven by the desire to understand the basis of how nature works.

Mr. **Walgren**. Thank you, Mr. MacKay.

Mr. Valentine.

Mr. **Valentine**. I don't have any questions. Thank you.

Mr. **Walgren**. Well, on behalf of the committee, thank you very much, Dr. Knapp. We will continue to be interested in your progress, and we want to drive you to think of any areas that need fixing before we find them, literally.

Dr. **Knapp**. Thank you.

Mr. **Walgren**. Perhaps we will be submitting some questions to you in writing for the record, and we do appreciate your cooperation.

The next panel is one on the university view of instrumentation, and it is made up of Dr. Donald Langenberg, the chancellor of the University of Illinois at Chicago; Dr. Alvin Kwiram, the chairman of the Council for Chemical Research; and Dr. George Olson, who is vice president for research at Colorado State University, if those gentlemen would come forward.

I understand Dr. Kwiram has a time constraint, and we would start with you at that point. Please know that your written statement will be made part of the record, reproduced in full, and if you would like to summarize your remarks we certainly would appreciate that.

Dr. **Kwiram**. Would you like me to begin, then?

Mr. **Walgren**. Yes, please.

STATEMENT OF ALVIN L. KWIRAM, CHAIRMAN, COUNCIL FOR CHEMICAL RESEARCH, INC., AND CHAIRMAN OF THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF WASHINGTON

Dr. **Kwiram**. Mr. Chairman, members of the committee, I am here in my capacity as chairman of the Council for Chemical Research. The written statement which I have prepared has been submitted, and I am going to try to highlight, in the limited time available, the rather novel character of the Council for Chemical Research; try to indicate what it is trying to accomplish; and then point out where we see the limitations, and the kind of issues that we think need to be addressed.

The driving force for the creation of the Council for Chemical Research was industry's concern, that concern focused on the problem of what they saw as some signs of ill health on the part of the basic research enterprise. CCR is a joint effort between industries and universities, the chemical industry in particular. At the present time there are something like 40 corporate members and over 130 university members on the council.

The representatives to the council are the senior technical executives from the companies, together with the heads of graduate departments of chemistry and chemical engineering in the Nation. Just to give you some sense of the companies involved, there is an attachment in my prepared statement which shows that these 40 companies had total sales for 1981 of something like $400 billion.

I am going to refer to this collection of activities—chemistry, chemical engineering, industry—as the chemical enterprise, so I do not have to make a distinction each time.

Let me put it in perspective just a bit. The chemical enterprise represents roughly 15 to 20 percent of the gross national product. Equally impressive, it contributed something like $12 billion last year to the balance of trade.

Now one of the questions we were asked to address is, what impact does the instrumentation obsolescence problem in the universities have on industry? I give a long answer in my prepared statement; let me give a short one here. Inadequate instrumentation affects both the training of students and the research productivity. The immediate consequence of that is a decrease in the innovative capacity of industry.

I think that is a very important consideration, because the economy is a concern for all of us, and the corporate members of CCR have felt very strongly—strongly enough to create CCR—that this is becoming a serious problem in the country.

Let me give you another example of the impact that inadequate instrumentation has, just by way of an anecdote: A couple of years ago we tried to hire a truly outstanding young woman chemist for our faculty. She looked at our instrumentation, she looked at what she would have to do to get going, and then she went to Sandia. The issue was, "You just don't have the instrumentation with which I think I can carry out the kind of research I want to do."

What is industry doing about this particular problem if it feels it is so important? One thing it has done is to create CCR, which I think is a rather remarkable thing in itself. The approach is to address the problem of the basic research enterprise systematically and cooperatively by involving the two major parties—academe and industry.

Before I describe what CCR is doing, I should make just a statement about the magnitude of the instrumentation problem. It has been stated here already by Dr. Knapp, that the instrumentation shortfall is something like $2 to $4 billion. This suggests that, at a minimum, something like $200 million needs to go into the instrumentation program on a constant basis simply to maintain the inventory—above and beyond renewal costs—because modern instrumentation has a lifetime of only about 5 years before it is obsolete—not because it is worn out but because it is technologically obsolete.

Now how does that relate to what has happened in the last few years, in fact? In chemistry, which is the area that I am most familiar with, it took about $10,000 to get a new faculty member started in 1970. In addition, he had to have access to something like $100,000 of pooled departmental equipment; that is, large equipment items.

By contrast, I just made an offer 2 weeks ago to a new faculty member in an area where it is hard to get faculty members. I might note that I just saw the bill that was passed in the House with regard to the matching program, where part of the proposed support was restricted to engineers. I assure you that hiring analytical chemists is every bit as serious a problem as for engineers, which is certainly a serious problem. However, the offer I made—which was stretching us to the absolute limit at this point in time—was $150,000 in startup money for this faculty member. He turned us down.

Today's faculty member needs access to at least $1 million of shared instrumentation. The increase has been a factor of 10 in the last decade. That is much higher than the CPI would suggest. Chemistry is no longer a question of test tubes, beakers, and bunsen burners. Dr. Knapp mentioned NMR, nuclear magnetic resonance, an absolutely essential tool for the modern synthetic chemist. He cannot function without it, not productively, at least. What is the cost? It is $150,000 to $600,000, depending on the capability.

Now, how important is this? Again, let me cite an example from our own experience, We hired a faculty member about 2 years ago. He thought it would take him 2 years to solve a particular problem having to do with DNA properties. We were fortunate to be able to get one of these sophisticated NMR instruments, and that problem can now be solved in 2 weeks.

In other words, these kinds of instruments are enormously cost effective due to the greatly increased productivity, and they are absolutely essential elements in today's fierce international competition for high technology products and markets. That is the view of the corporate members of CCR. In fact, the CCR board at its February meeting endorsed a recommendation from one of the standing committees that the problem of instrumentation obsolescence should be one of CCR's highest priorities.

Well, let's go back to the question of what the companies are doing about it, in general. I must say that when CCR started about 2 years ago, there was a great deal of enthusiasm that finally industry and academe were talking on a broad-scale basis about common problems. We had great visions that there would be millions and millions of dollars flowing into the academic enterprise by this means. Even some of our corporate members had that kind of enthusiasm.

Well, that has not quite developed. The support for higher education by the chemical companies had been excellent. In fact, I think I could advance information that would suggest it is probably about twice as good as the average for other industries.

However, in a survey carried out in 1981 by CCR, we found that the base level giving by the chemical industry to chemistry and chemical engineering departments alone was some $20 million. That is about 10 percent of the Federal support for basic research in these areas.

Let's say we could double that number, and let's say that as much as 25 percent of it could go for instrumentation, which may be a bit high because there are so many other needs that industrial funds serve. That means you have about a $5 million increase for instrumentation, which is less than 5 percent of the problem we are talking about. Therefore, the corporate and academic members quickly came to the realization that industry could do something. It could do something important, but it simply could not solve the entire problem.

Despite that, CCR has done a lot in the last year, in my opinion, and I can applaud them because I am not an industry person. CCR member companies last year increased their contributions by roughly $5 million to chemistry and chemical engineering departments alone. I think that is quite remarkable in view of the state of the economy. We would like to raise that number to about $10 million once the profit margins improve a bit, but the bottom line is that it is very unlikely that industry is going to be able to solve the problem.

Well, given this unpleasant reality, CCR, the board, and its committees, have seriously begun to address this problem and to try to analyze how this could be approached. I have outlined some of the ideas that have been explored in my written statement. They all have some attractive features but many of them have drawbacks.

We have talked about the matching program. We find that an attractive possibility. It was mentioned here earlier in the discussion with Dr. Knapp. We have given that some thought; we are still exploring it further, but the logistics are cumbersome. It is really kind of complicated to bring together independent company executives with the individuals from the universities, brokered by the NSF. To try to merge the interests of some 40 or 80 companies is not easy. I think it might be easier in the area of computer sciences, where there are a more limited number of actors.

However, one of the problems with chemical companies is that chemical companies do not make equipment. That is not their business. And although many of the chemical companies do donate equipment, used equipment, that is not state-of-the-art equipment. Universities really appreciate receiving such equipment, but it is usually 5 or more years old. The reason they are donating it is because they have no use for it any longer, and that is kind of ironic if we are talking about training people on state-of-the-art instrumentation so that they can go and increase the innovative capacity of industry.

However, the matching program is one that we find attractive. We have a particular kind of suggestion as to how that might be done; it has not been fully explored but it is illustrative of the kind of thing that CCR is certainly very interested in.

A set-aside program is another thing, with regard to the targeted R&D program of this Nation, that seems to be sustained by both compelling arguments and is of a magnitude that would be realistic. I would like to reiterate what was said earlier by Dr. Knapp, namely, that a one-shot infusion is not going to solve this problem. Instrumentation will continue to deteriorate, and we have to continue to replace it. It is like maintenance on a house, or a more recent and palpable example is that of our deteriorating transportation infrastructure such as our roads and bridges. We found what happened when we neglected that problem over an extended period of time.

In conclusion, I think the instrumentation obsolesence problems have been documented and studied and the issues are clear. There is not going to be a magic solution. No 3-year program is going to be adequate. The commitment must be strong and, more importantly, the commitment must be permanent.

Let me emphasize in that the chemical enterprise is an extremely important factor in the economic equation for this country. The corporate members of CCR feel strongly that a strong, basic research program in the universities is essential if the companies are to be effective in their own R&D efforts.

Therefore, on behalf of CCR I would like to urge that this committee act with foresight in tackling the problem of our aging and obsolete instrumentation. I think the kinds of things that have been done already are very positive, and we are very appreciative of that. We would just like to suggest that maybe another zero be added to the NSF allocation for equipment. That would begin to get into the ball park of the kind of need we see.

From the point of view of the chemical community and the chemical enterprise, we would like to urge that you take increasingly positive action before it is also too late for the chemical industry.

Thank you.

[The prepared statement of Dr. Kwiram follows:]

STATEMENT
OF
ALVIN L. KWIRAM
CHAIRMAN, COUNCIL FOR CHEMICAL RESEARCH
BEFORE THE
HOUSE SUBCOMMITTEE ON SCIENCE RESEARCH AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES
MARCH 8, 1983

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CCR BROCHURE

STATEMENT
OF
ALVIN L. KWIRAM
Chairman, Council for Chemical Research
Before the
House Subcommittee on Science Research and Technology
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INTRODUCTION

Mr. Chairman and members of the Committee. My name is Alvin L. Kwiram. I am Chairman of the Council for Chemical Research and am submitting this statement in that capacity. I am also chairman of the Department of Chemistry at the University of Washington in Seattle. Mr. James McEvoy, The Executive Director of CCR, is also here with me today.

I am pleased to have this opportunity to represent the views of the Council for Chemical Research before this Committee. The Council for Chemical Research was incorporated just over two years ago as a non-profit organization. CCR has a membership of 135 U.S. universities (virtually all the research universities) and 40 chemical companies, and is still growing. CCR is a unique organization because it is a joint effort by U.S.-based companies and universities to promote the health of the chemical sciences, engineering, and technology in this country. I shall refer to this collection of activities as the chemical enterprise.

CCR brings together the senior technical executives of the member companies and the department heads of the graduate chemistry and chemical engineering departments in the nation. One of the objectives of CCR is to improve cooperation and communication between industrial and academic scientists in order to stimulate creativity and to speed up technology transfer. Another of the primary objectives of CCR is to enhance the environment for basic research. This is recognized as an absolute necessity for the long term economic vitality of the industry in this country. The driving force for the creation of CCR in 1981 was industry's concern that the basic research enterprise was showing signs of ill health.

Let me try to put the chemical enterprise into perspective. In Table I I list the corporate members of CCR. Their sales figures alone for 1981 total a staggering $375 billion. The total sales for all chemical-related companies are estimated variously to comprise roughly 15-20% of the Gross National Product of the U.S.

Some 21,000 PhD-level chemists are employed in U.S. industry and the total number of chemists and chemical engineers is greater than 200,000. Another important factor I wish to call to your attention is the contribution of the chemical enterprise to our balance of payments figures. For 1980 (the latest figures which I had available) chemicals and chemical products contributed over 12 billion dollars to our trade balance, a figure exceeded only by "machinery and transportation equipment" on the positive side of the ledger.

In short, the chemical enterprise plays a major and critical role in the economic prosperity of this nation. Its continued health and vitality is a subject worthy of careful consideration.

In the remainder of my presentation I will provide a brief overview of the problem of instrumentation obsolescence and its impact, present the concerns of CCR on the subject, provide a few examples of what some CCR member companies are currently doing and can be expected to do in this area, and then briefly outline some possible options. After my presentation, Dr. Gerald Mantell from Air Products and Chemicals will provide specific examples of one company's activities and views on this matter.

OVERVIEW OF THE PROBLEM

The focus of this hearing is the problem of instrumentation obsolescence in university laboratories. Why should industry be concerned about this? Because the development of new products for the marketplace depends ultimately on progress in basic research. Most of the basic research in this country is carried out in universities. Therefore, if industry is to grow and remain competitive, the basic research enterprise must be vigorous and efficient. Equally important, the universities train the students which drive the intellectual wheels of industry. In the responses we solicited from member companies the important role of students trained in advanced up-to-date methods of measurement, analysis and interpretation was repeatedly emphasized. Robert Hefner from Dow states

> "Sometimes the formal training of students is seen to be sufficiently inadequate so as to actually limit their being hired into more sophisticated R & D operations. Often the theory being taught is either misunderstood or not understood because of the inability to demonstrate by practice. This has been known to result in significant inefficiencies and/or errors in research projects."

In other words, the roots of a thriving industrial organism must be firmly lodged in the college and university laboratories of this country. The health of the industry is only as good as the quality of the nutrients it feeds on. State-of-the-art instrumentation is a critical component in that research environment. Today the availability of these important tools is far too limited. This has been borne out in numerous studies (1,2) and articles.

The National Commission on Research published a report in May, 1980 entitled "Funding Mechanisms: Balancing Objectives and Resources in University Research". Of their nine recommendations, the first deals with "Equipment Obsolescence". They urge prompt action to reverse the deteriorating research equipment situation "...if the American research enterprise is to remain efficient and competitive internationally."

In June of the same year the Association of American Universities published a report submitted to the National Science Foundation entitled "The Scientific Instrumentation Needs of Research Universities". This was an extensive study which involved interviews with some 80 department heads and over 300 researchers and research administrators in universities, government and commercial laboratories in 5 fields of science and engineering. In July 1981 the AAU published a second report, this one entitled "The Nation's Deteriorating University Research Facilities." These excellent documents address most of the salient points in this matter. Almost exactly a year ago Professor George Pimentel submitted written testimony (3) to this committee in which he documented the need in some detail from the viewpoint of the universities. That information is equally valid today. I assume this material is available to the Committee. The conclusions reached in all these studies are the same—the academic research enterprise is suffering severe erosion due to the accelerating obsolescence of research instrumentation. Dr. George A. Keyworth, President Reagan's science adviser, has described this situation as "...disgraceful and deplorable."

THE SITUATION IN THE CHEMICAL SCIENCES AND ENGINEERING

I wish to reiterate just two points emphasized repeatedly in all these reports. First, the AAU report of 1980 compares the age of research instruments in universities and in industry. It states: "It is a telling fact that the instrumentation used in the top-ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories." More troublesome, the difference in median age is about the same as the average lifetime of much scientific equipment. In other words, the majority of students are trained or do research on technologically obsolete instruments (obsolete not in the sense that they are worn out—although some are—but in the sense that they have been superseded by new methods, new approaches). This is especially significant since universities are expected to provide students with the advanced training and research skills necessary to help industries remain competitive. (The situation in the undergraduate teaching laboratories is even worse than in the research laboratories.)

A second point deals with the rapid escalation in the capitalization cost for instrumentation. The report shows that capitalization costs doubled over a five year period for a major industrial research laboratory. That problem is significantly greater for chemistry. The report gives figures for the costs of setting up a new faculty member in Chemistry in 1970 and roughly 10 years later. In 1970 they show a figure of $8000; in 1979 it had risen to nearly $45,000, greater than a fivefold increase. Today that number is even higher. Equally important, that same faculty member in 1970 required access on a fairly routine basis to a central pool of departmental equipment costing roughly $115,000. Today that faculty member must have access to equipment costing roughly $750,000, nearly a seven-fold increase.

That factor may seem less exhorbitant if you compare it to the recent escalations in the cost of military hardware. The tools required for chemical sciences are no less sophisticated than those used in modern methods of defense. After all, the chemical enterprise is an integral part of the high technology enterprise. Indeed, David Boehm, the Harvard sociologist, has referred to chemistry as the first of the high technology enterprises. The foundation of all high technology is measurement. That is why instrumentation is such a critical need. Modern chemistry and chemical engineering simply cannot be done without modern measurement tools.

Over the past decade or two there literally has been a revolution in the technological sophistication of the tools necessary in chemical research. It is no longer simply a matter of beakers, test tubes and bunsen burners. Today nuclear magnetic resonance (NMR) is a routine and absolutely essential tool for the synthetic organic or inorganic chemist. The price tag for this tool ranges from $150,000 - $600,000 depending on the capabilities of the instrument. Moreover, 2 or 3 of these may be needed for different tasks at each major research university. Similarly, the synthetic chemist needs a mass spectrometer or two which can cost from $100,000 - $350,000. These are tools the research chemist must use virtually every day.

There are other factors which have dramatically altered the research environment in recent years that go far beyond the general deterioration due to inadequate resources. Some of these factors include the increasingly stringent requirements for limiting the exposure to chemicals. Today virtually all chemical reactions must be carried out in new and carefully monitored fume hoods. Similarly, in our search for contaminants in all contexts we now require expensive clean rooms and cold rooms, and special rooms to contain potential carcinogens. Rarely are provisions made for the purchase of such facilities.

In addition to the cost of the instrumentation itself, (which in many cases becomes part of a central facility shared by many researchers) attention must also be given to replacement costs, the costs of maintenance, and support for adequately trained operations personnel. Given the large investment in these facilities it is imperative that they be kept in excellent operating condition so they can be efficiently used around the clock.

Another important factor in the Instrumentation revolution is the computer which has provided productivity enhancements which are just as great for chemical research as they are for other sectors of the economy. The recent broad-scale introduction of microprocessors has rendered entire classes of instrumentation instantly obsolete via the conversion from analog to digital data collection, processing and manipulation. This transformation is taking place right now but the resources to acquire the new and much more powerful tools are woefully inadequate.

As Dr. James Porter of Exxon points out, scientific equipment manufacturers are investing nearly 15% of their total sales in R & D. They deserve our applause for the remarkable progress they have made in instrumentation development. Indeed, they are presenting the American chemical enterprise with an enormous opportunity to gain a significant competitive advantage if we act decisively and make these tools available to our research community. It represents a highly cost-effective investment in terms of greatly increased productivity and the opportunity to make dramatic strides in R & D.

Let me emphasize again that the chemical sciences in the eighties represent a truly high technology enterprise. The changes in methodology over the last decade or so have been dramatic. I would like to take the liberty of illustrating the impact of this change by one example from my own department. Roughly two years ago we hired a new faculty member whose research involves the chemistry of nucleic acids (DNA and RNA) which are at the heart of the current biotechnology revolution. He anticipated at the time that it would require two-three years of laborious synthetic chemical work to establish certain properties of these molecules. By a stroke of good fortune we were able to acquire one of those very expensive instruments I referred to earlier. To his delight and surprise he discovered that this new state-of-the-art NMR instrument had just enough sensitivity to answer the fundamental questions he was asking in just two weeks rather than two years. That, in turn, has led to some dramatic progress in the chemical synthesis and study of synthetic DNA fragments.

There are at least two important lessons to be extracted from this example: first, productivity is critically dependent on the quality of the research tools. Second, when we talk about an area such as biotechnology, which today represents an arena of intense international competition because of its commercial potential, the importance of having the necessary tools to do forefront research efficiently becomes a national economic priority.

To summarize this overview of the problem we re-emphasize three points:

1. There has been a dramatic revolution in the kind of instruments necessary for chemical research. The cost has increased nearly ten-fold in about a decade.
2. The nation's academic laboratories are falling behind, in terms of state-of-the-art facilities, and this is creating productivity problems as documented by several studies,
3. Support is also essential for maintenance and support staff for this advanced and diverse array of instrumentation, and
4. Continuing failure to respond adequately to this universally recognized problem will continue to erode our research competitiveness in the short term and our economic vitality in the long term.

THE ROLE OF THE CHEMICAL INDUSTRY

How large is the need for instrumentation? Is this a problem for the private sector to solve? The need is surely greater than a billion dollars for all the science and engineering disciplines. Estimates of $2-4 billion have been advanced. Last year the DOD announced a $30 M program for instrumentation aimed primarily at those engaged in research of interest to the agencies. Despite a relatively short deadline, they received nearly 3,000 proposals requesting a total of roughly $3/4 billion. Even if one assumes that not all of that equipment is crucial, the numbers themselves are compelling. (At the very least it shows that there were thousands of faculty members out there concerned enough to give up a couple of weeks of precious time to put together a proposal.) Professor Pimentel used an alternative analysis to arrive at a figure of roughly $50 million per year for Chemistry alone. If equipment needs in the intermediate price range ($50,000 - $500,000) are added for other disciplines as well, then an annual figure of over $200 million is reached.

Let me turn briefly to the concerns of the chemical industry in this context. One of the major standing committees of the Council For Chemical Research, chaired by Robert Hefner of Dow Chemical, identified the instrumentation problem in universities as one of its highest priorities. The concern on the part of industry is that the universities' research labs are not working with state-of-the-art facilities. This has serious consequences from the industry point of view, as suggessted earlier. The net result is a decrease of the innovative capacity of industry. Indeed, I think it is fair to say that one of the primary motives for the creation of the Council for Chemical Research was the recognition that unless industry gave these issues serious attention, the economic vigor of the chemical industry could be seriously jeopardized. This is a matter of great concern to the members of CCR.

The chemical industry has an excellent record of supporting higher education and these contributions cover a very wide spectrum of disciplines and objectives. A year ago, Professor Judson King carried out a survey on behalf of CCR which showed that about $20 million a year (excluding contracts) was going specifically to chemistry and chemical engineering departments. This represents roughly 10% of the total support for basic research in these fields provided by the federal government. The corporate members of CCR have indicated that it would be unrealistic to think that this amount could be increased dramatically. In other words even increased corporate support for basic research in the chemical sciences cannot be viewed as an alternative to increased government support of basic reseach in this arena. Nevertheless, because of their strong concern, CCR member companies committed nearly $5 million last year in new money (in addition to the $20 million or so) to be granted to university researchers in the chemical sciences and engineering. However, many other problems, besides instrumentation, which are not adequately supported by federal funds also clamor for attention--the need for unrestricted funds, for funds to help new faculty get started, to make teaching careers in science and engineering more attracive, as well as funds for supplies, for fellowships, for support personnel, and so on.

Thus, the conclusion is that industry, however concerned and committed, simply is not in a position to make a significant impact on the instrumentation problem.

Dr. Mantell will give some examples later to illustrate what Air Products is doing within this context. Their efforts are fairly typical of what a number of other CCR companies are doing. Although such efforts by industry are important and very much appreciated by the universities the impact is small compared to the need. It is important to keep the matter in perspective.

How could the situation be improved? By way of illustration I would like to outline a few approaches that have been suggested in various quarters and considered by CCR. CCR has been in contact with OSTP and other branches of government, and we will continue to refine and recommend these and other approaches.

SUGGESTED RESPONSES TO THE INSTRUMENTATION PROBLEM

1. Universities should engage in more debt-financing to acquire major instruments. This is an approach that can be very valuable in selected cases, but it must be kept clearly in mind that it doesn't create any new funding. It simply provides a mechanism for diverting the funds normally allocated for operations and personnel. Thus, it does not deal with the underlying problem. In this case the approach in the university stands in sharp contrast to that in industry for quite sensible reasons. A company will engage in debt financing because an acquisition now can lead to greater profits later with which to pay the debt. It can also take advantage of tax benefits. Universities, on the other hand, can hardly be considered profit centers. Recently, OMB circular A-21 has been amended to permit interest payments from grants. That will help. Nevertheless, debt financing is not a universal solution for the universities. Under special circumstances it can be used effectively, and this approach should certainly be evaluated further.

2. Chemical companies should donate more equipment or equipment funds to universities. As I have noted earlier many corporations have an ongoing program of equipment donations, but even if such contributions were doubled, less than 5% of the problem would be addressed. Nevertheless, some refinement of the Economic Recovery Tax Act of 1981 to include the following options would be helpful.

- Permit the use of fair market value for donation of new equipment.
- Permit the use of fair market value for used but relatively new equipment.
- Allow expanded tax credit for a grant of funds earmarked specifically for equipment acquisition.

In the case of the chemical industry, virtually none of the companies manufacture instruments that are routinely used in a university research environment. Moreover, once a company is willing to part with a particular used instrument it is quite unlikely that it is still a state-of-the-art item.

On the other hand instrument manufacturers, especially those that make many of the sophisticated pieces of equipment mentioned earlier, are often relatively small companies and in many cases are foreign-based companies. Thus, there is little incentive to donate new equipment of the sort most needed. CCR suggests that ERTA provisions be refined in this connection but recognizes that this approach cannot solve the problem.

3. The federal government should provide incentives for matching programs involving industry and the states with the federal government to renew the university research laboratories. Most companies support this approach as a general principle, but the challenge is to design a workable mechanism to implement such a program. It is clear from our experience in CCR that

a case-by-case matching program for equipment would be very cumbersome and probably impractical. There is, however, a more general approach which is very attractive.

I mentioned earlier that CCR established what the corporate contributions to the base-level funding in the chemical sciences was as of a year ago. We recommend that the federal government establish a challenge program of matching funds for instrumentation acquisition in universities along the following lines. For every dollar donated by companies for the support of basic research in universities above the base-level funding of last year, the federal government would add two dollars to the NSF budget earmarked specifically for equipment. There are many variations on this theme which are attractive but I will not argue the details here. Suffice it to say that such a cooperative venture between industry and the government to improve the basic research environment in this country would be a novel and highly salutary development. CCR urges that this approach be considered seriously. Again, it would not solve the problem, but the impact would be palpable. Moreover, it would encourage companies to make a long term investment in basic research in areas of interest to them.

4. Establish a set-aside fund as a percentage of the federal funds designated for targeted and/or mission oriented research and development (the TR & D portion of the R & D budget), for instrumentation. There are several attractive features in this approach.

a. The effectiveness of targeted research and development depends critically on the basic research which has preceded it. Hence improving the quality of the latter is essential for enhancing the efficiency of the former. Indeed, it could be argued that the money set-aside would improve the productivity of the basic research labs to such a degree that the benefits to the targeted research and development program would more than offset the very modest investment.

b. One of the essential resources for targeted research and development is highly trained personnel. These come from the universities and colleges. Therefore the allocation of a small portion of the budget so that students would be trained on state-of-the-art instrumentation represents a prudent investment.

c. Only the TR & D budget is large enough to provide resources through a set-aside program commensurate with the magnitude of the instrumentation problem without seriously distorting the objectives of the funding agency.

d. The TR & D effort places demands on a very broad range of disciplines and therefore represents a logical starting point for underwriting the enterprise.

On behalf of CCR, I would like to urge that such an approach be given serious consideration. A set-aside of one-half of one percent of the TR & D budget plus an equivalent amount (somewhat over $100 million) allocated directly to NSF would represent an appropriate response to this problem.

What has to be recognized is that the problem of obsolete instrumentation is not going to be solved by a one-shot infusion of funds even if the dose is massive. We are dealing with an enormous inventory problem for capital equipment which is continually aging and losing its effectiveness. The problem is similar to the deteriorating transportation infrastructure such as our roads and bridges.

When we eat a piece of fresh fruit or buy a piece of furniture we don't think about the crucial role our transportation system plays in making that possible. Likewise, when we fill our gas tank with refined fuel, drive our cars with catalytic converters, use our miniaturized consumer electronics devices and computers with their extraordinarily high purity silicon chips with complex chemically processed surfaces, when we paint our houses, when we put on our clothes made of synthetic fabrics, eat the food which has been produced in abundance due to advances in fertilizers, pest control and genetic manipulation (and has been checked for contamination by the sophisticated tools of chemistry), and recover from our illnesses through the miracle of modern pharmaceuticals...(the list is endless)... we don't think about the chemistry and chemical engineering which has made all these things possible. Like our roads and highways which connect our cities, towns and farms, the chemical enterprise is intimately connected with virtually every facet of our lives. And just as in the case of our transportation network, we can shortchange the system for a while with no immediate, dramatic consequences. But the effect is insidious and when the cumulative deterioration finally reaches crisis proportions, the bill to remedy the problem is so gargantuan that we become paralyzed. Instead of bold and resolute action we merely commission another study, hoping a magic solution will be found.

There is no magic solution to the instrumentation gap. What is required beyond the tacit recognition of the fundamental problem, is a program which systematically and automatically provides some base level of support to replace and upgrade the existing inventory. Given the magnitude of the problem, it cannot be solved by converting a portion of the normal grant resources into equipment funds. (This procedure has been used very successfully by the Chemistry Division at NSF for many years, but at a high price--the percentage of proposals funded has dropped to well under 50% of those still trying and for new faculty members the success rate is closer to an unacceptably low 25%. See Figure III attached. Despite this, NSF funds only 50% of the instrument cost.) No three year program or five year program is adequate. The commitment must be strong and it must be permanent.

The chemical enterprise is an extremely important factor in the economic equation for this country. At the same time there is a growing concern that this industry may be undergoing significant structural academe, industry and government to ensure creative, high quality research on a broad range of topics.

That brings us back to the tools needed for the job. On behalf of the corporate members of CCR I would like to urge this committee and the Congress to act expeditiously and with foresight in tackling the problem of our aging and obsolete instrumentation resources. When one of the corporate members of CCR was told of this hearing and the figure of $6 million being considered for the NSF instrumentation program in chemistry he was convinced that we had dropped a zero someplace. We urge this committee to take a bold and courageous action, not just to approve but to increase the NSF instrumentation request significantly. All you need to do is add a zero The need has been documented in repeated studies. Let's act before it is also too late for the chemical industry which plays such a vital role in this nation's economy.

FOOTNOTES

1. See also the report of the ad hoc workshop held on March 12-13, 1982 under the auspices of the National Research Council; "Revitalizing Laboratory Instrumentation" National Academy Press, Washington, D.C. 1982.

2. An extensive survey of this problem was carried out last year by the American Chemical Society. A report summarizing the results will be available shortly.

3. Testimony of George C. Pimentel before the House Subcommittee on Science, Research and Technology, March, 1982.

TABLE I

CORPORATE MEMBERS OF CCR

COMPANY	SALES ($000)
EXXON	108,107,688
GULF OIL	28,252,000
ATLANTIC RICHFIELD	27,797,436
GENERAL ELECTRIC	27,240,000
E.I. du PONT de NEMOURS	22,810,000
SHELL	21,629,000
OCCIDENTAL PETROLEUM	14,707,543
STANDARD OIL (OHIO)	13,457,091
DOW CHEMICAL	11,873,000
PROCTER & GAMBLE	11,416,000
EASTMAN KODAK	10,337,000
WESTINGHOUSE	9,367,500
GOODYEAR TIRE & RUBBER	9,152,905
XEROX	8,691,000
MONSANTO	6,947,700
MINNESOTA MINING & MANUFACTURING	6,508,000
ALLIED	6,407,000
JOHNSON & JOHNSON	5,399,000
COLGATE-PALMOLIVE	5,261,364
CELANESE	3,752,000
AMERICAN CYANAMID	3,649,073
FMC	3,581,960

PPG INDUSTRIES	3,353,600
PFIZER	3,249,700
B. F. GOODRICH	3,194,600
BORG-WARNER	2,761,200
SMITHKLINE BECKMAN	1,985,341
ROHM & HAAS	1,884,664
STAUFFER CHEMICAL	1,726,236
AIR PRODUCTS & CHEMICALS	1,570,115
LUBRIZOL	878,291
DOW CORNING	721,861
NALCO CHEMICAL	666,591
AMOCO CHEMICALS CORPORATION*	
GTE LABORATORIES, INC.*	
INMONT CORPORATION*	
SUNTECH, INC. *	
UOP, INC. *	

* Sales Figures not available.

TABLE II

UNIVERSITY MEMBER OF CCR

The University of Alabama
The American University
Arizona State University
The University of Arizona
University of Arkansas
Atlanta University
Auburn University
Boston University
Brandeis University
Brown University
California Institute of Technology
University of California, Berkeley
University of California, Los Angeles
University of California at Riverside
University of California, San Diego
Carnegie-Mellon University
Case Western Reserve University
University of Central Florida
Central Michigan University
University of Chicago
University of Cincinnati
City University of New York
Clark University
Clarkson College of Technology
Clemson University
Colorado State University
University of Colorado
Columbia University
University of Connecticut
Cornell University
Dartmouth University
University of Delaware
Drexel University
Duke University
Emory University
Florida State University
University of Florida
Georgetown University
Georgia Institute of Technology
University of Georgia
Harvard University
University of Houston
Howard University
University of Idaho
Illinois Institute of Technology
U. of Illinois at Chicago Circle
U. of Illinois at Urbana
Iowa State University
University of Iowa
Johns Hopkins University
Kansas State University
University of Kansas
University of Kentucky
Lehigh University
Louisiana State University
University of Louisville
Marquette University
University of Maryland
MIT
U. of Massachusetts, Amherst
Memphis State University
University of Miami
Michigan State University

Michigan Technological University
University of Michigan
University of Minnesota
Mississippi State University
University of Mississippi
University of Missouri-Columbia
University of Missouri-Rolla
University of Missouri-St. Louis
Montana State University
University of Nebraska-Lincoln
University of Nevada
University of New Hampshire
New Mexico State University
University of New Orleans
New York University
North Carolina State University
University of North Carolina
North Dakota State University
Northeastern University
Northwestern Universtiy
University of Notre Dame
Ohio State University
Ohio University
Oklahoma State University
University of Oklahoma
Oregon State University
University of Oregon
The Pennsylvania State University
University of Pennsylvania
University of Pittsburgh
Polytechnic Institute of New York
Princeton University
Purdue University
Queens College - CUNY
Rensselaer Polytechnic Institute
Universityof Rhode Island
Rice University
University of Rochester
Rockefeller University
Rutgers University
Seton Hall University
University of Southern Mississippi
Stanford University
SUNY at Buffalo
College of Staten Island
Syracuse University
University of Tennessee
Texas A&M University
Texas Tech University
University of Texas at Austin
Tufts University
University of Utah
Vanderbilt University
Villanova University
Virginia Polytechnic
University of Virginia
Washington State University
Washington University
University of Washington
Wayne State University
Wesleyan University
West Virginia University
University of Wisconsin-Madison
University of Wisconsin-Milwaukee
Worcester Polytechnic Institute
The University of Wyoming
Yale University

NATIONAL SCIENCE FOUNDATION

SUCCESS RATIOS ON REVIEWED PROPOSALS
-CHEMISTRY DIVISION-

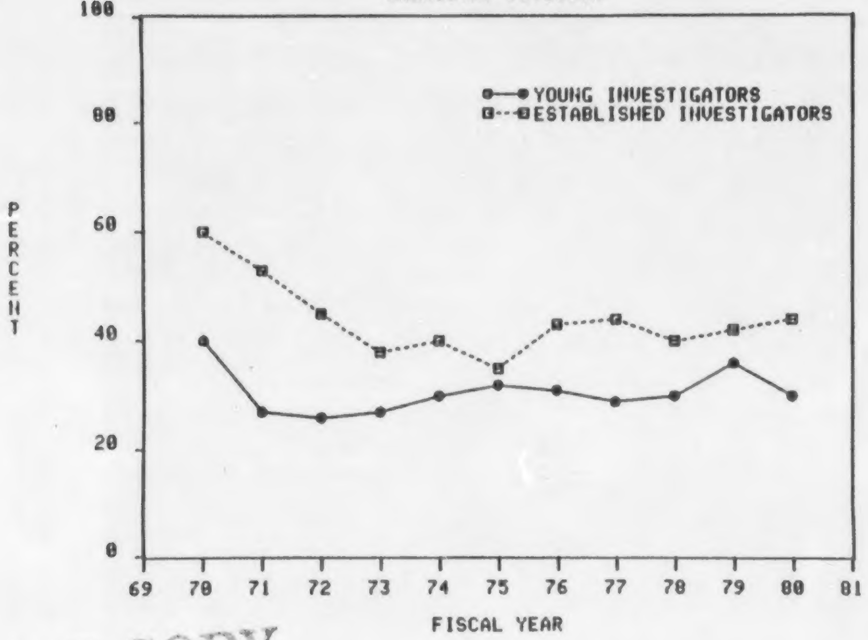

TABLE III

Mr. **Walgren**. Thank you very much, Dr. Kwiram. It was suggested that you could stay with us until 4:15 or thereabouts, or is that your plane time?

Dr. **Kwiram**. No, I can stay until 4:15.

Mr. **Walgren**. All right. We will then proceed to Dr. Langenberg, and go through the rest of the panel of statements before reaching into discussion.

Dr. Langenberg.

STATEMENT OF DONALD N. LANGENBERG, CHANCELLOR, UNIVERSITY OF ILLINOIS AT CHICAGO

Dr. **Langenberg**. Thank you, Mr. Chairman.

Mr. Chairman and members of the committee, you have asked me to present my views on the current status of university research instrumentation, and particularly to assess the effectiveness of the Federal response to the instrumentation problem in our Nation's research universities. I very much appreciate the opportunity to do this, for this is an issue in which I have had a personal interest in a number of roles—as an experimental physicist, as a university administrator, as Deputy Director of the National Science Foundation, and now again as a university officer. I consider myself to be here today, however, as an individual, not representing any particular institution.

The evidence for a deficit in the research instrumentation capabilities of our universities began to accumulate more than a decade ago. In my prepared statement I run through some of the background, leading up to the following expression of my current view. My view of the present situation with respect to university research instrumentation is that we have a serious national problem—you will note I said national, not Federal—a national problem which has not and will not go away, and which deserves serious attention by Governments, both Federal and State, by private industry, and by the university research community.

I think the gap between our present university research instrumentation capability and what it ought to be to insure maximum productivity by our most creative and innovative researchers, corresponds to at least $1 billion and probably a good deal more. A year ago when I reported to this subcommittee, I presented $1 billion as a lower bound and suggested that some estimates go as high as $3 or $4 billion.

There are some encouraging signs that the problem is being addressed, however, by Federal and by State Governments, by private industry, and by the scientific and engineering research communities. You have asked me to address the Federal part of that effort, and this I would like to do in the context of the Interagency Working Group on University Research Instrumentation.

As Dr. Knapp has already told you, the Interagency Working Group on University Research Instrumentation was organized back in mid-1981 by NSF with the support of the Director of the Office of Science and Technology Policy. He has noted that it is composed of senior Presidential appointees representing the Foundation, agriculture, defense, energy, NASA, and NIH. I chaired that group until my departure from the Foundation in December 1982 and it is currently chaired by the Director of the Foundation, Dr. Knapp.

A year ago I talked to this subcommittee on the Interagency Group's formation and early findings. Since then, it has reviewed agency budgets for university research and has worked jointly to assure the maximum possible fiscal year 1984 budget request for instrumentation. It has reviewed the process for implementing the DOD instrumentation program begun in fiscal year 1983. It has discussed possible accelerated cost recovery proposals for university-funded equipment purchases, and it has discussed concerns by commercial laboratories over competition from NSF-funded instrumentation in universities. Finally, it has adopted a multifaceted national program to address the instrumentation program.

The elements of that program are listed on this chart, and a copy of that chart is appended to the prepared statement. I would now like to discuss each of them in turn.

First of all there is data acquisition. There has been some unease expressed about the estimates, both their magnitude and their evident imprecision, the estimates of the size of the instrumentation problem. This committee has asked NSF to develop indicators of the status of research instrumentation, in the spirit of the indicators of the state of science and technology which are reported periodically by the National Science Board in its science indicator series. I assume that the Foundation has and will keep you informed of the progress of this project. Dr. Knapp has already mentioned it.

I think that if it is successful, this project should provide us a tool with which to monitor continuously the status of university research instrumentation, to refine our estimates of the magnitude of the current problem, to assess the effectiveness of our efforts to ameliorate it, and to understand better the differing nature of research instrumentation needs among the fields of science and engineering.

Now when I mentioned a moment ago the existence of some recent indications of the magnitude of the instrumentation problem, I had in mind in the back of my mind a very recent indication that suggests that the earlier estimates that you have heard are really not far off the mark. This is the response of the scientific community to the Department of Defense's instrumentation program mounted in fiscal year 1983. As Dr. Knapp has noted, DOD has received something like 2,500 proposals in competition for those funds, totaling something close to three-quarters of a billion dollars in requested Federal funds, requests of almost three quarters of a billion dollars for a total program size of $30 million. It seems to me that that response indicates that our earlier estimates are not really far off the mark.

You could argue, perhaps, that those proposals contain a good many frivolous wish-list requests, and may greatly overstate the need. That may be the case but I very much doubt it.

First of all, the DOD program requires substantial cost sharing on the part of the proposing institutions. I'm sorry—it does not require it but it very strongly encourages it. Furthermore, the preparation of a proposal where the probability of success was perceived, I think, by everybody to be very low—a priori—and a posteriori appears to be only about 4 percent, is not a task any scientist would undertake lightly.

Taken together, these facts suggest to me that the incidence of frivolous proposals is unlikely to be high. Furthermore, if you recognize that the fields of research eligible for DOD support—although the guidelines were rather broadly defined—exclude some of the physical sciences and exclude much of the biological and agricultural sciences—that is to say, include only a part of the full range of sciences funded by NSF in its programs—then it seems to me that that response to the DOD program provides some additional experimental support for an estimate of the university research instrumentation deficit in the billion-plus range.

I will pass over the second item on that list, called "funding initiatives," because these describe the initiatives in the budgets of the agencies represented on the Interagency Group related to instrumentation, and those I think you are familiar with to a substantial degree, particularly the National Science Foundation's budget. I would note, however, the numbers: the $90 million, the $30 million, the $10 million, and the $6 million are specific program level increases in those agencies for instrumentation over previous levels. Those are not the total amounts; they are the increases. You can see, and I should say that the increases are over the period 1982 to 1984, so that is a 2-year increase, and over that period you can see a program level increase for instrumentation of $136 million across those agencies represented there.

The next item here is labeled "stimulate donations and discounts." Dr. Knapp has already referred to several experiments performed by NSF in the last year, one of which involved direct donations of equipment and the other, substantial discounts on equipment. It seems to me that those represent directions of some promise for the future. The National Science Board has encouraged Foundation staff to explore other opportunities for such cooperation with the private sector, and these initial examples have been discussed and endorsed by the Interagency Group.

The Economic Recovery Tax Act of 1981 had provisions intended to stimulate donations of research equipment by manufacturers to universities. NSF has initiated with manufacturers, both individually and through industry associations, some efforts to encourage use of those incentives of the tax act. The response has been mixed and I think on the whole, to me at least, rather disappointing.

Some manufacturers are increasing equipment donations but often, it appears, for reasons that do not appear to be especially related to the tax act incentives. Others report that current economic conditions militate against donations—if there are no profits, there are no taxes, and then there is no incentive to donate—but still others report that they are awaiting issuance of the IRS regulations implementing the relevant provisions of the tax act so that they can judge what the value of the incentives is, and here we seem to have a major problem.

I don't know why IRS, more than a year after the passage of that act, has not yet issued regulations, but the delay here is, I think, nullifying the effect of those incentives that the Congress built into the act. Every day that goes by—because of the "within 2 years" production requirement of that act—more equipment becomes ineligible for donation. Despite some prodding by the Director of the National Science Foundation, there has not been any visible result so far, and I would urge OSTP and, if necessary, the Congress, to press the IRS to do its job and get those regulations out. The donation provisions could potentially be a substantial contribution to the solution of the research instrumentation problem, if manufacturers knew what the ground rules were for using them.

The next item there says, "focus small business set-aside," and that refers to the Small Business Development Act of 1982 which, as you are well aware, required set-asides in the budgets of the R&D funding agencies for support of R&D for small businesses. The Interagency Group has discussed the idea that some portion of agencies' small business programs might be focused specifically on small businesses that are engaged in developing highly sophisticated research instrumentation.

It is a well-known fact, in the scientific game at least, that an awful lot of businesses begin with small businesses which are devoted to taking ideas developed in the laboratory and converting them into commercially usable instrumentation, and very often first for use back in the laboratory. One well-known example is the laser which, when it was first commercially manufactured, was in fact manufactured as a tool for use in laboratories, and now you find them everywhere, including in every supermarket checkout stand. The Foundation, I believe, and some of the other agencies represented on the Interagency Group are looking with considerable favor on focusing at least part of that small business set-aside on instrumentation firms.

Then there is university management. I am prepared to proclaim the virtues of the American research university but I am not, I am afraid, prepared to present these universities as general paragons of crisp and tight management. There are a good many good and proper reasons for that, given the particular character of universities. Nonetheless, I think there is a growing awareness, even within universities, that there is room for improvement, particularly in the area of managing acquisition, maintenance, and use of research instrumentation.

Most of the agencies represented on that interagency group have committed themselves to support a major project, which will be carried out under the leadership of three university organizations—the AAU, NASULGC, and the Council on Governmental Relations—and those acronyms are all explained in the prepared statement. That project will include the commissioning of six analyses: first, to assess the role of debt financing for research equipment in sound university financial practice—and Dr. Olson, my colleague here, will be talking to you a good deal about that shortly; second, to identify and evaluate opportunities to improve procurement, management, utilization, operation, and maintenance of research equipment; third, to assess present tax incentives for the donation of research equipment, and suggest ways to increase support from the private sector; fourth, identify opportunities to eliminate or reduce State and university budget and other policy barriers; fifth, to identify opportunities for changes in Federal regulations; and sixth, to evaluate present modes of direct Federal investment and suggest future improvements.

There are also plans to spread the good word through a series of seminars scheduled to coincide with professional and association meetings, regional meetings, and a national symposium.

The last item there says, "stimulate Government laboratories." Some of them seem to be quite well stimulated already. However, what is meant there is that if one notes that the federally funded laboratories of the country, a major scientific resource, absorb a considerable part of the Nation's R&D budget and contain a great deal of highly sophisticated research instrumentation, one might ask whether that might be used more effectively than it now is by university researchers.

Now in some fields, of course—high energy physics, astronomy—the very purpose of these Federal laboratories is to provide facilities and instrumentation to university researchers, but in many fields it may be that one could make available those facilities and instrumentation without compromising the purposes of the laboratory. The Interagency Group is considering that question. DOE is about to issue an agency-wide publication encouraging external use of DOE facilities and equipment, and I believe this question and this issue deserves very careful attention.

That program I have outlined there is an ambitious one. It includes roles for Governments, both Federal and State; Federal agencies, industry, universities, and the scientific and engineering communities. No one of those elements alone can solve the instrumentation problem. Each of them will help, and taken together, they may turn the trick.

I see in the budget initiatives for instrumentation in 1983 and 1984, and in the elements of the Interagency Group's program, the beginnings of an effective attack on the instrumentation problem. As I have noted, the program level increases over there in budget are at $136 million; that is a pretty good start. I am especially encouraged by the National Science Foundation's plans for 1984. In the current economic climate, I think they represent a remarkable achievement by the leadership of the Foundation and of OSTP, and I very much hope the Congress will find it possible to support them.

However, if we are going to make real inroads on the instrumentation problem, I believe further, substantial budget initiatives must be made by the other agencies, and in addition to money, I think the Federal Government must continue to provide leadership. It cannot do the whole job by itself. The scientific and engineering communities, the universities and industry, must do their part, but I think the importance of Federal leadership can be seen in the nonbudgetary elements of that interagency group's national program and they can be seen elsewhere.

Finally, I think we have to stick to our guns. We made a good start on solving a problem that has developed over more than a decade. It may take the better part of another decade to complete the job, and for this effort I think stay the course is truly an appropriate admonition.

Mr. Chairman, that completes my statement.

[The prepared statement of Dr. Langenberg follows:]

STATEMENT OF
DR. DONALD N. LANGENBERG
CHANCELLOR, UNIVERSITY OF ILLINOIS AT CHICAGO
BEFORE THE
SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES
MARCH 8, 1983

Mr. Chairman and Members of the Committee,

You have asked me to present my views on the current status of university research instrumentation and particularly to assess the effectiveness of the federal effort to address the instrumentation problem in our Nation's research universities. I appreciate this opportunity to do so, for this is an issue in which I have had an active interest in several roles, as an experimental scientist, as a university administrator, as Deputy Director of the National Science Foundation, and now again as a university officer. I consider myself to be here today as an individual, however, not representing any institution.

The evidence for a deficit in the research instrumentation capabilities of our universities began to accumulate more than a decade ago. It appeared first in the complaints of scientists who found it increasingly difficult to find funds to keep their research programs going and also acquire new equipment needed to exploit new ideas and techniques. Those returning from visits to colleagues (and competitors) abroad began to describe enviously the superior instrumentation and facilities they had seen there. Surveys and studies were performed or sponsored by university associations and by federal agencies, notably NSF and NIH. These all supported a growing recognition that the problem was real, large, and growing larger. When I appeared before this Subcommittee a year ago, I said that the magnitude of the problem was difficult to specify with precision, but that a rough lower bound of one billion dollars was a reasonable estimate, with some estimates ranging up to three or four billion dollars. Elsewhere I have given two billion plus or minus a factor of two as my guess at the size of the deficit. Some have expressed uneasiness about the evident lack of precision and the impressive magnitude of this estimate. Later I will describe steps being taken to address the former concern, and some recent indications that the magnitude is not overstated.

How did we get ourselves into this fix? Some of the reasons are fairly obvious. Federal funding for university research increased dramatically through the fifties and sixties, then essentially plateaued. The response from university researchers was that typical human managerial response, i.e., maintain support for people, defer capital investment (equipment acquisition), and pray for better times. Meanwhile, the substantial infusions of instrumentation which had come with massive capital expansion by the universities in the fifties and early sixties were becoming obsolete, with little prospect for replacement from university sources. The ingenuity of our scientists and engineers further exacerbated the situation: new techniques and new instruments were invented, making it possible to detect and measure things undreamed of not long ago. Unfortunately, with a few exceptions like computers, the new state-of-the-art instrumentation is more expensive as well as more sophisticated, this on top of inflation.

A federal response to the university research instrumentation problem began to appear in the late seventies, e.g., in several programs of the National

Science Foundation. These were the result of commendable initiatives by agency program managers and officials but were few and scattered. The President's January, 1980 Budget Request to the Congress for FY1981 contained an agency-wide initiative for the Foundation, which fell victim to the March revision. Again in January, 1981, the President's request included a research instrumentation initiative for the Foundation, this time at the level of $75 million, but again this vanished in the new administration's March revision. Frustrating as this was for many of us, it was paralleled by a more positive development extending throughout this period, the spreading recognition of the seriousness of the university research instrumentation problem, in the scientific and university communities, in state and federal administrations, in the Congress, and in private industry. I am reminded of the observation that when the practitioners in a field identify a problem, you have a problem; when those in related areas learn about it, you have a big problem; and when the administrators, the politicians, and the news media learn about it, you have a crisis! This process is still continuing, but it appears to have advanced to the point where substantial responses to the "crisis" are beginning to appear in several quarters.

My view of the current situation with respect to university research instrumentation, then, is that we have a serious national problem which has not and will not go away and which deserves serious attention by governments, by private industry, and by the university research community. The gap between our present university research instrumentation capability and what it ought to be to ensure maximum productivity by our most creative and innovative researchers corresponds to at least a billion dollars, and probably more. There are encouraging signs that the problem is being confronted, however, by federal and state governments, by private industry, and by the scientific and engineering research communities. You have asked me to address the federal part of this effort. This I would like to do in the context of the work of the Interagency Working Group on University Research Instrumentation.

The Interagency Working Group on University Research Instrumentation was organized in mid-1981 by the National Science Foundation, with the support of the Director, Office of Science and Technology Policy. It is composed of senior Presidential appointees representing the Foundation, the Department of Agriculture, the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, and the National Institutes of Health. These agencies account for about 95% of all federal funding for university research and development. I chaired the Interagency Group until my departure from the Foundation in December, 1982; it is currently chaired by the Director of the Foundation.

The Interagency Group has served as a vehicle for focusing high-level agency attention on the university research instrumentation problem. Its members discuss a variety of issues and proposals, agree on general policy directions, and monitor staff follow-up. Not all the represented agencies have been equally aggressive in attacking the instrumentation problem, and their approaches to it display considerable diversity. This is as it should be. Different agencies and the various scientific and engineering disciplines have different styles and varying instrumentation needs. The instrumentation problem is not monolithic and it has no single, sweeping solution.

A year ago, I reported to this Subcommittee on the Interagency Group's formation and early findings. Since then, it has:

- reviewed agency budgets for university research and worked jointly to assure the maximum possible FY 1984 budget requests for instrumentation;
- reviewed the process for implementing the DoD intrumentation program begun in FY 1983;
- discussed possible accelerated cost recovery proposals for university-funded equipment purchases;
- discussed concerns of commercial laboratories over competition from NSF-funded instrumentation in university laboratories;
- adopted a multi-faceted national program to address the instrumentation problem.

The elements of this national program are listed in the appended chart. I would now like to discuss each of them in turn.

Data Acquisition. This Committee has asked NSF to develop "indicators" of the status of research instrumentation, in the spirit of the indicators of the state of science and technology reported periodically by the National Science Board in its "Science Indicators" series. I assume the Foundation has kept you informed of the progress of this project. Briefly, a pilot survey was conducted in the fall of 1981. Analysis of the results led to the design of an instrumentation indicator survey instrument which was reviewed by the Interagency Group and further refined. The survey questionnaires were sent out in December, 1982. A report on the results should be available by fall, 1983. The survey covers a stratified sample of 40 institutions drawn from among the top 160 performers of academic research and development. The first round will cover the physical sciences and the next the biological sciences.

If successful, this project should provide us a tool with which to monitor continuously the status of university research instrumentation, to refine our estimates of the magnitude of the current problem, to assess the effectiveness of our efforts to ameliorate it, and to understand better the differing nature of research instrumentation needs among the fields of science and engineering.

Other studies of the instrumentation problem have been or are currently being performed by the American Chemical Society, the American Geophysical Union, the American Electronics Association, and the North Carolina State Legislature.

When I mentioned earlier the existence of recent indications of the magnitude of the instrumentation problem, I had in mind the response of the scientific and engineering communities to the FY 1983 DoD Instrumentation Program. This was the first of this administration's targeted responses to the problem, providing $30 million for instrumentation applicable to research in areas relevant to the DoD mission. DoD has received 2500 proposals in the competition for these funds, totaling [redacted] nearly three-quarters of a billion dollars in requested federal funds. I believe this response indicates that our earlier estimates of the size of the university research instrumentation deficit are not far off the mark. One might argue that this flood of proposals may contain a great many frivolous "wish-list" requests and thus may greatly overstate the real need. Perhaps, but I doubt it. The DoD program encourages substantial cost-sharing by the proposing institutions. Furthermore, the preparation of a competitive proposal where the probability of success is seen a priori to be low (and a posteriori appears to be about 4%) is not a task any scientist would undertake lightly. Taken together, these facts suggest that the incidence of frivolous proposals is unlikely to be high. Further, if one recognizes that the fields of research eligible for the DoD program, broadly defined though its guidelines are, exclude some of the physical sciences and much of the biological and agricultural sciences, then it seems to me that the first-year response to the DoD program provides additional support for an estimate of the university research instrumentation deficit in the billion-plus range.

Funding Initiatives. The President's FY 1984 Budget Request to the Congress reflects a very substantial response to the university research instrumentation problem. The DoD instrumentation program initiated in FY 1983 is slated to continue, at the same level of $30 million. I would like to note that DoD worked closely with the Interagency Group in developing the concept, design, and selection criteria for its program, providing a good example of interagency cooperation. I should also note that there is a continuing concern in some quarters that the DoD program may be funded at the expense of other DoD funding programs for university research and may thus not represent a real increase in support for university research instrumentation. I don't know whether this is so or not, but would suggest that the question deserves Congressional scrutiny.

The NSF budget contains a major instrumentation thrust for FY 1984. The agency has already presented its budget to this Subcommittee, so I will just note a couple of highlights. Proposed funding for research instrumentation is up 60% from FY 1983, 100% from FY 1982. The Foundation intends to manage its instrumentation programs in a dispersed mode rather than in a single centrally managed program. This is a deliberate strategy, intended to ensure the best possible fit between available funds and the differing needs of the disciplines. Most of the funds will be invested through individual project grants, or major facilities. However, a significant portion will be handled by special instrumentation programs at the division (disciplinary) level. These programs will operate at a level of approximately $55 million, more than double their level in FY 1982.

DoE has proposed a $6 million special instrumentation initiative in FY 1984, intended for equipment costing $100 thousand or more, to be used in energy-related research by major universities. Maintenance and operational costs are eligible for support in this program, in addition to acquisition costs. This is a valuable and important feature, one I would urge other agencies to adopt in their instrumentation programs.

NIH's FY 1983 budget shows a $10 million increase for instrumentation in the Division of Research Resources Special Equipment Program. This 200% increase over the requested amount ($5 million) was initiated by Congress in an action I heartily applaud.

NASA has not established a separately identifiable instrumentation program, but has issued a directive to its program officers to give special consideration to instrumentation in awards to universities.

USDA is giving continued consideration to means of focusing on research instrumentation in its R & D programs.

Stimulate Donations and Discounts. During FY 1982, NSF initiated two interesting experiments which suggest ways in which federal programs might be meshed with private sector efforts to address the instrumentation problem. The first involved a science and engineering education program in which grantees develop computer software ("courseware") for the teaching of mathematics, science, or engineering. This was really a continuation of a long-standing Foundation program of this kind. The new feature here was that no Foundation funds were provided for computer acquisition under the program. Rather, the necessary computers were donated by five manufacturers to recipients of NSF awards chosen through the normal peer-review process. The total value of the donations exceeded $900 thousand, while the total NSF funds obligated were substantially less than this amount.

The other experiment was performed in a program to provide computing equipment for research in the mathematical sciences. A single manufacturer agreed to provide an exceptionally deep discount (45%) to all program awardees requesting that manufacturer's equipment, permitting the Foundation to fund more proposals and to equip those funded more adequately.

The National Science Board has encouraged Foundation staff to explore other opportunities for such cooperation with the private sector, and these initial examples have been discussed and endorsed by the Interagency Group.

The Economic Recovery Tax Act of 1981 has provisions intended to stimulate donations of research equipment by manufacturers to universities. NSF has initiated with manufacturers, both individually and through industry associations, efforts to encourage use of the incentives of the Tax Act. The response has been mixed and, on the whole, disappointing. Some manufacturers are increasing equipment donations, but often for reasons apparently unrelated to the Tax Act incentives. Others report that current economic conditions preclude donations; if there are no profits, there are no taxes and hence no incentives to donate. Still others report they are awaiting issuance of IRS regulations implementing the relevant provisions of the Tax Act, which will enable them to judge the value of the incentives. Here we seem to have a major problem. Whatever may be the reasons for the failure of IRS to have issued these regulations, more than a year after passage of the Act, the delay is nullifying the effect of the incentives the Congress built into the Act. Because of the requirement that equipment be donated "within two years of production", more equipment becomes ineligible with each day of further delay. The Director of the National Science Foundation wrote the IRS in April of 1982 to ask that the regulation-writing process be expedited, with no visible result so far. I would urge OSTP and, if necessary, the Congress to press the IRS to do its job. The donation provisions may be a relatively minor matter in the general tax structure of the country, but they could have a significant positive effect on the research instrumentation problem, if manufacturers knew what the ground rules were for using them.

Small Business Set-Aside. In 1982, the Congress passed the Small Business Development Act, requiring set-asides in the budgets of R & D funding agencies for support of R & D by small businesses. The National Science Foundation's Small Business Innovation Research Program, initiated in 1977, was identified in the Act as a prototype for small business programs established under the Act. The Interagency Group has discussed the idea that some portion of the agencies' small business programs might be focused specifically on firms engaged in developing highly sophisticated research instrumentation. This might increase the incentives for rapid transfer of new instrumentation ideas from university laboratories to commerce, enhance university-industry interactions, and promote the development of important new technologies, which often begin with the development of instrumentation for laboratory use before moving on to broader markets. (An example is the laser, which moved from the laboratory to commercial manufacture first as a laboratory tool. Now they're found in every supermarket check-out stand.)

The Foundation's Small Business Innovation Research Program has historically encouraged instrument manufacturers to compete. To date, the program has received 238 proposals from such firms and has made 26 awards. The Foundation expects to give added emphasis to small instrumentation firms as its SBIR program expands in size under the provisions of the Act. Other agencies, notably DoE, are providing similar emphases in their programs.

University Management. One way to attack a problem like the one under discussion is to provide added resources. Another is to use the resources in hand more efficiently, wisely, and creatively. While, as a university administrator, I am prepared to trumpet the many virtues of the American research university, I would not be prepared to present universities as paragons of crisp, tight management. There are good and proper reasons for that in the special character and nature of universities. Nevertheless, I believe there is increasing awareness in the university community that improvements in the way we manage the research instrumentation problem are possible.

Most of the agencies represented in the Interagency Group have committed themselves to collaborative support of a major project to increase awareness among research universities of opportunities for better planning and management of research instrumentation resources, at all levels from the bench scientist to boards of trustees. The project will be carried out under the leadership of three university organizations, the Association of American Universities, the National Association of State Universities and Land Grant Colleges, and the Council on Governmental Relations, of the National Association of College and University Business Officers. It will include the commissioning of six analyses to:

- assess the role of debt financing for research equipment in sound university financial practice;
- identify and evaluate opportunities to improve the procurement, management, utilization, operation, and maintenance of research equipment;
- assess present tax incentives for the donation of research equipment and suggest ways to increase support from the private sector;
- identify opportunities to eliminate or reduce state and university budget and other policy barriers;
- identify opportunities for changes in federal regulations;
- evaluate present modes of direct federal investment and suggest future improvements.

Also included are plans to propagate information and understanding through twenty seminars scheduled to coincide with professional and association meetings, three regional meetings, and a national symposium. I believe this project has great potential for inducing changes in the managerial and planning practices of universities and their scientists and engineers, to optimize use of scarce resources in providing university research instrumentation.

Government Laboratories. The laboratories supported by many agencies of the federal government are a major national scientific resource, absorb a large portion of the federal R & D budget, and contain a great deal of highly sophisticated research instrumentation. One is led to ask whether this instrumentation might more effectively be made available to university researchers, where feasible, than it now is. In some fields, such as high energy physics and astronomy, provision of facilities and instrumentation already is the central purpose of federally-funded laboratories. But in other fields and in other laboratories, it may be that laboratory facilities and instrumentation might be used by university researchers, without compromising (and, indeed, perhaps enhancing) the performance of the laboratory. The Interagency Group is considering this question, as is, I am told, the current OSTP review of the federal laboratories. DoE ~~has issued~~ is about to issue an agency-wide publication encouraging external use of DoE facilities and equipment. I believe it deserves careful attention. If appropriate service to the university research community could be established as part of the mission of many federal laboratories, rather than an occasional ancillary purpose, I think this would be a significant contribution to solution of the instrumentation problem.

The national program of the Interagency Working Group on University Research Instrumentation which I have outlined here is an ambitious one. It includes roles for governments, federal agencies, industry, universities, and the scientific and engineering communities. No one of its elements can alone solve the instrumentation problem. Each will help, and taken together they may do the trick.

I see in the budget initiatives for instrumentation in FY 1983 and 1984, and in the elements of the Interagency Group's national program, the beginnings of an effective attack on the instrumentation problem. The instrumentation program level increases from FY 1982 to 1984 shown in the chart total

$136 million. That's a good start. I am particularly encouraged by the National Science Foundation's plans for FY 1984. In the current economic climate, they represent a remarkable achievement by the leadership of the Foundation and of OSTP. I hope the Congress will find it possible to support them. But if we are going to make real inroads on the instrumentation problem, I believe further substantial budget initiatives must be made by the other agencies. And in addition to money, I believe the federal government must continue to provide leadership. It cannot do the whole job by itself; the scientific and engineering communities, the universities, and industry must do their part. But I think the importance of federal leadership can be seen in the non-budgetary elements of the Interagency Group's national program, and elsewhere. Finally, I believe we must stick to our guns. We have a good start on solving a problem which has developed over more than a decade. It may take the better part of another decade to complete the job. For this effort, I think "stay the course" is truly an appropriate admonition.

Mr. Chairman, that completes my statement. I would be pleased to answer any questions you and your colleagues may have.

Mr. **Walgren**. Thank you very much, Dr. Langenberg.

Dr. Olson.

STATEMENT OF GEORGE G. OLSON, VICE PRESIDENT FOR RESEARCH, COLORADO STATE UNIVERSITY

Dr. **Olson**. Thank you, Mr. Chairman, members of the committee.

I believe I was invited here to speak because of the debt management program we have been involved in at Colorado State University for the past several years. My thesis to this problem is, "Isn't it time we helped ourselves?"

It is estimated that universities will conduct $6 billion of research activity this year, funded from both public and private sources. Let us suppose that we need $1 billion in new equipment to start the rehabilitation of university laboratories. Why not finance this? One billion dollars of new equipment, financed at 10 percent over the next 5 years, would cost us $264 million per year or just 4.4 percent of our total budget. This is less than half of what our counterparts in industry spend from their research budgets for research instrumentation.

The debt financing of scientific equipment provides benefits other than just the acquisition of hardware. First, it provides equipment now when it is needed. Scientific progress is not delayed while waiting for an equipment grant that may or may not arrive and when it does, only provides half the needed funds. Tax-exempt interest rates are generally lower than the inflation rate on equipment, so besides obtaining equipment now, we will never obtain it at a lower cost.

Second, debt financing encourages better management on the part of university administration. When asked to undertake a debt financing program, administrators develop an awareness and interest in the research program and actively participate in its planning and growth.

Third, debt financing results in improved equipment utilization. When a professor struggles to get a grant for a piece of equipment for his laboratory, it is his, and it probably ought to be. He may or may not share it. However, debt service on equipment generally comes from a number of sources. Shared use means lower cost, and it becomes the preferred mode of operation. Debt financing can ensure the constant upgrading of equipment and its planned replacement.

Fourth, debt financing develops diversified funding support for equipment. Debt service is met by user charges for the equipment. This means that all agencies, public and private, supporting research utilizing a particular piece of equipment, share in the cost of that equipment—not just the National Science Foundation.

Can debt financing work? It has at Colorado State University, where about $40 million of scientific equipment has been provided to our research program. The mechanisms that we have used and some of the facilities that we have financed are summarized here:

Revenue bonds have been used to fund a laboratory for disease control, a research farm, and our first scientific computer.

Industrial development bonds have been issued by the appropriate city or county to provide a $6.6 million research service building, the $9 million Cray I computer which we lease to the National Center for Atmospheric Research, and we have a pending issue for the Cyber 205 supercomputer for our National Supercomputer Network. Colorado State University is the only agency in the world to own both a Cray I and a Cyber 205.

Municipal lease-purchase contracts: This method of financing is used to provide innumerable pieces of equipment costing between $100,000 and $1 million. These have included satellite tracking stations, a computer operating system, many VAX and minicomputers, various aircraft, electron microscopes and so on.

For small pieces of equipment we use tax-exempt revolving lines of credit that our Foundation maintains at two local banks. This revolving line of credit provides the stock in trade of the small equipment, from a few thousand to $100,000, that is needed by all of our researchers.

Obviously, once you have borrowed the money to finance equipment it must be repaid. This is generally accomplished through user fees paid by the research projects for the use of equipment. User fees always include both principal and interest payments for acquiring the instrument, and they may include such other expenses as maintenance, operators, and so forth.

Until the recent amendment to OMB Circular A-21, interest on equipment financing was not allowable unless the instrument was leased from an arm's-length agency. This was one of the reasons that we have used an affiliated but arm's-length agency, the Colorado State University Research Foundation, to manage our debt financing.

We believe that equipment acquisition and financing ought to be the responsibility of the university. It is the responsibility of Congress to support basic research through appropriations to the National Science Foundation and other agencies. Basic research budgets should include an adequate allowance for use charges for state-of-the-art scientific equipment. Once universities begin to manage their own equipment acquisitions on a businesslike basis, they will continually be upgrading their scientific equipment in response to demands from the growth and development of their own research program.

I would like to close with a practical comment and a request for assistance from this committee.

Debt financing is not easy. It requires the manipulations of many different kinds of financial instruments; the cooperation of investment bankers to sell unrated story bonds or story paper; and, finally, the careful and expensive opining of tax counsel. The requirements of OMB Circular A-21, complexities of the IRS code, and the innumerable IRS regulations discourage many university administrators from going forward with an equipment financing program.

The legislation I have had the audacity to propose here would, in summary, make interest on obligations of colleges and universities and their not-for-profit organizations for the acquisition of equipment and facilities for scientific or educational purposes tax-exempt. In summary, you could give me $1 billion today, I will go home and upgrade my laboratories, but in 5 years I will be back because by then it will be out-of-date, except I won't ask for $1 billion, I will ask for $2 billion because it will have inflated to that price by then; or you could make it easier and more direct for us to do our own debt financing, and perhaps you will never see me again.

Thank you.

[The prepared statement of Dr. Olson follows:]

Statement of
Dr. George G. Olson
Vice President for Research
Colorado State University

Before the
Subcommittee on Science Research and Technology
U.S. House of Representatives
March 8, 1983

Mr. Chairman and Members of the Committee:

The direct relation between this country's declining leadership in high technology and the obsolescence of our university scientific equipment has been well established in the recent book published by Harper and Row, "Global Stakes, The Future of High Technology in America".

Traditionally, the solution to the problem of equipment acquisition has come as outright grants from university budgets, state appropriations, endowment funds, corporate gifts or the federal government. These sources at best are irregular, inadequate and in times of severe budget constraints, improbable.

Isn't it time we helped ourselves? It is estimated that universities will conduct $6 billion of research activity this year funded from both public and private sources. Let us suppose that we need at least $1 billion in new equipment to start the rehabilitation of our university laboratories. Why not finance it? One billion dollars of new equipment financed at 10% over the next five years would cost us $264 million per year or just 4.4% of our total budget. We learned last year at the National Research Council Workshop on Revitalizing Laboratory

Instrumentation that the ratio of capital expenditures to operating budgets in industrial research laboratories was about 9%. We are talking about less than half that amount over the next five years to provide us $1 billion in new equipment now. Obviously, if we only wanted to acquire $250 million in new equipment under the same terms, our debt service would be only one-fourth as much, or barely 1% of our total expenditures for research.

Universities can and must adopt a businesslike approach to equipment financing in order to provide constant upgrading of their facilities on a regular, planned basis. The free enterprise system has developed the mechanisms to address this problem. Simply stated, we need to establish our objectives for research, assess our needs to achieve those objectives, evaluate our fiscal resources, plan our cash management, conduct a risk assessment and, if warranted, undertake debt financing to achieve our objectives. Unlike their counterparts in business, universities have available to them many more mechanisms for debt financing that are under more favorable, tax-exempt terms. These include revenue bonds, industrial development bonds, municipal leases, and tax-exempt lines of credit.

The debt financing of scientific equipment provides other benefits beyond just the acquisition of hardware.

First - It provides equipment now, when it is needed. Scientific progress is not delayed while waiting for an equipment grant that may or may not arrive and when it does, only provides for half the needed funds. Tax-exempt interest rates are generally lower than the inflation rate on equipment, so besides obtaining equipment now, and including interests costs, it is never going to be cheaper.

Second - Debt financing encourages better management on the part of the university administration. When asked to undertake a debt financing program, administrators develop an awareness and interest in the research program and actively participate in its planning and growth.

Third - Debt financing results in improved equipment utilization. When a professor struggles to get a grant for a piece of equipment for his laboratory, it is his and it ought to be. He may or may not share it. However, debt service on equipment generally comes from a number of sources, and shared use means lower costs and it becomes the preferred mode of operation. Debt financing also assures constant upgrading of equipment and its planned replacement.

Fourth - Debt financing develops diversified funding support for equipment. Debt service is met by user charges for the equipment. That means that all agencies, public and private, supporting research utilizing a particular piece of equipment, share in the cost of that equipment - not just the National Science Foundation.

You may question why go to all the trouble of debt financing when it would be so much simpler just to lease a piece of equipment. Certainly leasing should always be investigated and if it is less expensive, it should be considered. However, there are still some advantages to debt financing. Unlike industry, where prudent judgment may allow a new piece of equipment to lose money the first year, break even the second, and contribute to profits the third, universities must generate debt service from the first day equipment is acquired. On major pieces of equipment, debt financing can be structured so that the first year's debt service is capitalized and actual payments are not required until the second year. This gives the laboratory time to "shake down" the equipment, develop a user base, and overcome low utilization at first.

Can debt financing work? It has at Colorado State University where about $40 million in scientific equipment and facilities have been provided through the debt financing activities of the Colorado State University Research Foundation (CSURF). The mechanisms CSURF has used and some of the facilities financed are summarized here:

> Revenue Bonds - Issued on behalf of the university have provided: a laboratory for disease control, a 200 acre research farm, an irrigation system, a CDC 6400 computer.
>
> Industrial Development Bonds - Issued by the appropriate city or county for CSURF have provided: $6.6 million research service building, a $9 million Cray-I computer which we lease to the National Center for Atmospheric Research in Boulder, Colorado, a pending issue for a Cyber 205 supercomputer for our National Supercomputer Network.

Municipal Leases - Purchase Contracts - This method of financing has been used to provide innumerable pieces of equipment costing between $100,000 and $1 million. These have included a satellite tracking station, a computer operating system, VAX and other mini-computers, aircraft, word processing systems, electron microscopes, X-ray equipment, radiation counters, etc.

Tax-exempt Revolving Lines of Credit - CSURF maintains two revolving lines of credit at local banks which are used to buy small pieces of equipment costing from a few thousand dollars to $100,000. This equipment is the stock in trade of the individual researcher. It is generally leased directly to a project on rather short amortization schedules. This fund turns over constantly to provide CSU researchers a readily available source of small equipment.

Obviously, once you have borrowed money to finance equipment, it must be repaid. This is generally accomplished through "user fees" paid by research projects for use of the equipment. User fees always include the basic principal and interest payments for acquiring the instrument and may include such other expenses as maintenance, operators, etc. Until the recent amendment to OMB Circular A-21, interest on equipment financing was not allowable unless the instrument was leased from an arms-length agency. This was one of the reasons we have used an affiliated, but arms-length organization, the CSU Research Foundation, to manage our debt financing.

Can debt financing of scientific equipment have a major impact on the recovery of high technology leadership in this country? I believe it can and will use the acquisition of supercomputers as an example.

One of the basic requirements today for state-of-the-art capability in most fields of high technology is access to advanced computers. The decline of American preeminence in many fields of academic research can be directly related to the lack of availability of state-of-the-art computers on university campuses. For example, no American university ever acquired a CDC 7600 computer although it was the top scientific computer from the time it was introduced in 1966 until the advent of the supercomputer in 1977. Yet, during that time, a number of universities in Europe acquired CDC 7600 computers and a number of them have already acquired the current state-of-the-art supercomputer, either a Cray-I or a Cyber 205. The fact that these computers are not available to American university researchers not only limits the quality of their research, but means that they are not training graduate students in writing modern codes, they are not exploring new computational methods and are actually falling behind their counterparts in Western Europe and Japan in the basic elements of computer science.

The capital cost of a supercomputer facility is in the range of $7 to $10 million depending on the size of computer memory, ancillary equipment, power sources, etc. It is costs of this order of magnitude that have prevented universities from acquiring state-of-the-art scientific computers for the past 16 or 17 years. It is not likely that such funds will become available from federal sources for scientific equipment acquisitions.

Colorado State University, through its Research Foundation, has addressed this national problem in the following ways: In 1977 it acquired a Cray-I computer and leases it to the National Center for Atmospheric Research for the support of their research program. In 1982, the CSU Research Foundation installed a two million word, two vector pipeline Cyber 205 supercomputer in the computer center at Colorado State University. The Foundation proposes to make this facility available to the university community through a national computer network utilizing selected regional universities as nodes or regional network centers. Last month, the first of these nodes or centers was established at the University of Massachusetts and serves New England through the Dartmouth Kiewit Network.

We believe that equipment acquisition and financing ought to be the responsibility of the university. It is the responsibility of the Congress to support basic research through appropriations to the National Science Foundation and other agencies. Basic research budget should include an adequate allowance for use charges for state-of-the-art scientific equipment. Once universities begin to manage their own equipment acquisitions on a businesslike basis, they will be continually upgrading their scientific equipment in response to demands from the growth and development of their own research programs.

I would like to close with a practical comment and a request for assistance from this subcommittee. Debt financing is not easy. It requires the manipulation of many different kinds of financial instruments, the cooperation of an investment banker to sell unrated "story bonds" or paper, and finally, the careful and expensive opining of tax counsel. The requirements of OMB Circular A-21, the complexities of the Internal Revenue Code of 1954 as amended, and innumerable IRS regulations discourage many university administrators from going forward with an equipment financing program.

This whole complex business could be greatly simplified by your enacting legislation which would amend Section 103 of the Internal Revenue Code of 1954 to provide the following:

> "Interest on the obligations of colleges, universities, and not-for-profit organizations for the acquisition of equipment and facilities for scientific or educational purposes shall be tax-exempt."

A copy of proposed legislation which would accomplish this is attached for your convenience.

Such a bill would have no negative impact on tax revenues as it would merely simplify what can be done at the present time. It would, however, stimulate the financing of scientific equipment by universities which will enhance their ability to contribute to the resurgence of America's technical leadership.

A BILL

To revise section 103 of the Internal Revenue Code of 1954 (relating to tax-exempt bonds).

(1) Section 103(a) --

(A) Paragraph (1) of section 103(a) is amended by striking out "and".

(B) Paragraph (2) of section 103(a) is amended by striking out "." and inserting in lieu thereof "; and".

(C) Paragraph (3) is inserted to read as follows: "(3) qualified scientific facilities and equipment bonds."

(2) Section 103(m) --

(A) Paragraph (n) is redesignated by striking out "(n)" and inserting in lieu thereof "(o)".

(B) A new paragraph (n) is inserted to read as follows:

(n) Qualified Scientific Facilities and Equipment Bonds. -- For purposes of subsection (a), the term "qualified scientific facilities and equipment bonds" means obligations

(1) issued by an organization described in section 501(c)3 which is organized and operated exclusively for scientific or educational purposes, and

(2) the proceeds of which are used to finance scientific facilities or equipment for scientific or educational purposes.

Debt Financing by Universities: How to Get Equipment Without Cash

FORT COLLINS, COLO.

University researchers are learning how to get the expensive new laboratory equipment they need without having the cash on hand to pay for it.

Basically, it's a matter of leasing equipment or buying it on the installment plan and making the payments with money earned by charging for use of the equipment.

The details are often complicated and may require the advice of investment bankers and tax lawyers, says George G. Olson, vice-president for research at Colorado State University here, who has conducted seminars on debt financing for university administrators. Familiar examples of such financing are home mortgages and time payments for automobiles.

Colorado State has used several types of debt financing to get some $10-million worth of scientific equipment and facilities over the past 15 years, he said.

For example, equipment for receiving and analyzing weather data from space satellites was acquired for the university's atmospheric-science department in 1978 through a "municipal lease."

The university leased the equipment from a bank for six years at 7½-per-cent interest. Because the lease is on a year-to-year basis, the university does not officially incur any debt. Principal and interest are recovered through charges to research sponsors. At the end of the six-year lease, the equipment will be paid for and will become the university's property.

Mr. Olson said he had found widespread interest in debt financing of scientific equipment, but few universities had actually used it.

Representatives of some 30 universities attended each of two seminars he has conducted—one in New York last fall and another in Denver this spring. Mr. Olson has also advocated debt financing in talks at a dozen universities and at a seminar sponsored by the education division of the Control Data Corporation in May.

Colorado State evidently was the first university to use revenue bonds to finance the purchase of a computer, Mr. Olson said.

Not the Best Way to Buy

Colorado State's research foundation issued $1.3-million in bonds at 4.75 per cent in 1966 to buy the computer for the university's center for disease control. The bonds were paid off by 1978, and the foundation turned over the ownership of the computer to the university.

The lack of a direct precedent made it difficult, but eventually Colorado State obtained the necessary ruling from the Internal Revenue Service that the bonds for the computer were tax-exempt, Mr. Olson said.

Debt financing is not the best way to buy scientific equipment, he said, but for many institutions it may be the only way, because funds for outright cash purchase are not available.

The federal government's reduction of nondefense spending is adding to the general financial problems at the institutional and state levels. More directly, the Reagan Administration, in its budget for fiscal 1982, eliminated a $75-million program that had been included in the Carter Administration's budget to help universities upgrade their research equipment.

Several national studies have found that much of the equipment in university laboratories is deteriorating or is obsolete.

The Association of American Universities, after surveying laboratories at 24 institutions last year, warned that the United States could fall behind its competitors overseas if it did not provide adequate funds for renovation ~~and new equipment~~.

The National Research Commission, a private agency, which last year completed a two-year study of university research policy and support, said the problem of obsolescence in the laboratory called for "imaginative funding devices."

"Steps must be taken soon to address this problem if the American research enterprise is to remain efficient and competitive internationally," the commission said.

The commission recommended consideration of debt financing, with debt and interest payments to be included in charges to research sponsors for use of the financed equipment.

"We believe that research-supporting agencies should make clear to investigators, peer reviewers, and universities the acceptability of equipment-use charges," the commission said. "These charges would allow timely acquisition of important pieces of equipment while distributing the cost over a convenient time period."

Lewis M. Branscomb, chairman of the National Science Board, recently recommended that universities lease more scientific equipment to replace obsolescent instruments and to avoid a "periodic national equipment crisis."

One of the troublesome aspects of debt financing, Mr. Olson said, is getting the sponsors of research projects to pay equipment-use fees that include interest payments, which at today's rates can be substantial.

Financing the purchase of equipment through a nonprofit third party, usually a foundation associated with the university, often solves problems of interest payment and gets around restrictions that bar many state institutions from incurring debt directly.

Third-Party Rules

Federal rules on costs that can be covered by research grants generally exclude interest on a university's direct financing of equipment, but permit interest charges to be included when the university is leasing the equipment from a third party, such as a research foundation.

Because such foundations are nonprofit charitable institutions and the interest paid to lenders is tax-exempt, they can borrow money at relatively low rates.

At Colorado State, much of the debt financing is handled by the Colorado State University Research Foundation.

The foundation was originally an agency of the university, operated by university employees, but in 1979 it was reorganized as an independent agency with its own trustees and staff. That gave it a legal "arm's length" standing so it could serve as a third party in leasing equipment to the university, said the foundation's president, Cynthia J. Hanson.

The foundation used industrial-development bonds in 1978 to finance a $9-million computer for the National Center for Atmospheric Research, a facility in Boulder operated by a consortium of universities that includes Colorado State.

The Boulder County government issued the bonds for 10 years at 6 per cent on behalf of the research foundation. The foundation purchased the computer from the manufacturer and leased it to the research center. The center pays a rental fee that includes a charge to cover principal and interest. At the end of the lease period, the foundation will own the computer, which it has agreed to sell to the center for a token $25.

The foundation has a line of credit at a bank, at tax-exempt interest rates, with which it finances smaller equipment purchases of from $10,000 to $50,000.

"The selection of the appropriate debt instrument," Mr. Olson told university officials, "is best made in cooperation with an investment banking firm and legal tax counsel experienced in this type of financing."

The National Commission on Research, in advocating debt financing to upgrade university laboratories, recommended that federal regulations be revised to permit "routine reimbursement of interest charges."

Such a change would eliminate the need for a third party in debt financing.

—JACK MAGARRELL

COLORADO STATE UNIVERSITY

Antennas to receive data from satellites were obtained by Colorado State University through debt financing

FACT-FILE

Science and Engineering Graduates of 1977 and Their Employment Status 2 Years Later

Field of study	Employed in field †	Employed outside field	Unemployed	Not in labor force ‡	Total graduates
Bachelor's degrees					
Physical sciences	6,500	8,800	500	600	16,200
Chemistry	3,200	2,100	100	200	5,600
Physics, astronomy	400	1,300	100	0	1,800
Environmental	2,800	4,400	300	300	7,800
Other	200	700	100	0	1,000
Mathematical sciences	10,800	7,000	100	100	18,000
Mathematics	5,800	6,100	100	200	12,300
Computer sciences	4,800	900	0	0	5,800
Engineering	39,500	5,000	600	100	45,800
Life sciences	18,200	31,000	1,600	1,500	52,300
Biology	8,900	23,400	1,300	1,100	34,700
Agricultural sciences	9,300	7,600	300	400	17,600
Social sciences	9,000	71,400	4,200	5,200	89,800
Psychology	4,000	27,000	1,800	3,500	36,300
Economics	1,500	8,400	700	300	10,900
Sociology, anthropology	2,200	21,200	1,300	1,000	25,700
Other	1,300	14,800	400	500	17,000
Total, bachelor's degrees	**84,000**	**123,500**	**7,000**	**7,700**	**222,200**
Master's degrees					
Physical sciences	2,400	1,800	0	200	4,400
Chemistry	900	300	0	100	1,300
Physics, astronomy	300	400	0	0	700
Environmental	1,100	900	0	100	2,100
Other	100	200	0	0	300
Mathematical sciences	3,100	2,200	200	200	5,700
Mathematics	1,500	1,300	200	0	3,000
Computer sciences	1,700	700	100	100	2,600
Engineering	12,900	1,800	100	100	14,900
Life sciences	4,100	3,600	200	200	8,100
Biology	2,600	2,300	200	200	5,300
Agricultural	1,500	1,300	0	0	2,800
Social sciences	5,100	6,400	400	400	12,300
Psychology	3,300	2,700	200	200	6,400
Economics	1,000	800	100	0	2,000
Sociology, anthropology	700	1,000	100	200	2,000
Other	300	1,600	0	0	1,900
Total, master's degrees	**33,600**	**9,800**	**900**	**1,000**	**45,300**

† Those whose degree and employment fall within the same broad category.
‡ Includes those enrolled full time in graduate school.

SOURCE: NATIONAL SCIENCE FOUNDATION

Many Science, Engineering Graduates Take Jobs in Other Fields, NSF Finds

WASHINGTON

More than half of the graduates receiving bachelor's degrees in science or engineering take jobs outside the field they were trained for, the National Science Foundation reports.

At the master's-degree level, only a fifth of the graduates take jobs in their field, the N.S.F. study shows.

The foundation surveyed science and engineering graduates of 1977 to see what their employment status was two years later.

Of the 45,300 graduates who had received their master's degrees in science or engineering, 33,600 were employed in their field, 9,800 were employed in other fields, 1,000 were continuing their graduate studies or were out of the job market for other reasons, and 900 were not employed and were looking for jobs.

Among the 222,200 who received bachelor's degrees in science or engineering in 1977, an estimated 84,000 were employed in their field in 1979, 123,500 had jobs in other fields, 7,700 were in graduate schools or otherwise out of the job market, and 7,000 were unemployed.

The report, *Employment Attributes of Recent Science and Engineering Graduates*, notes that although a substantial proportion of science and engineering graduates were not working in their fields, unemployment rates were low—3 per cent at the bachelor's-degree level and 2 per cent at the master's-degree level.

At the bachelor's-degree level, 55 per cent of the men but only 37 per cent of the women had jobs in science or engineering. At the master's-degree level, the comparable percentages are 79 per cent for men and 58 per cent for women.

—J.M.

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(Chemical & Engineering News, June 1, 1981)

Debt financing: academia's funding alternative

Universities can purchase replacements for obsolete equipment with tax-exempt loans, rather than the usual cash from grants, contracts

Rudy M. Baum
C&EN. San Francisco

C&EN staff photo

Colorado's Olson (left), Hanson: any university could use debt financing

To business, the idea is anything but new. Money is borrowed to purchase needed equipment or facilities, and the loan is paid back over a period of time with interest. But to colleges and universities seeking funds to purchase scientific equipment and facilities for research, the concept is a bit radical.

It isn't radical to George G. Olson, vice president for research at Colorado State University, Fort Collins. In the past 17 years, he has been involved in using various tax exempt debt mechanisms to purchase more than $25 million worth of scientific equipment and research facilities. And Olson thinks a number of factors will force other universities to turn to debt financing as well.

A number of recent reports, including the joint Department of Education-National Science Foundation report, "Science and Engineering Education for the 1980's and Beyond," and the reports of the National Commission on Research, have made the point that much university scientific equipment is obsolete. This obsolescence is hurting scientific research and education directly, and it contributes to universities' problems in holding onto high-quality faculty members in the face of competition from industry.

At the same time, funds earmarked for equipment purchases are drying up. When the National Science Foundation's chemistry division was told to cut $2 million from its fiscal 1981 budget, the funds came out of the equipment budget. And the Reagan Administration's proposed 1982 NSF budget eliminates a new program that would have provided $75 million for new equipment (C&EN, April 20, page 21).

Universities usually have purchased scientific equipment after raising the money to pay for it. The money has come from direct state and federal appropriations, endowment

Tax-exempt financing can take several forms

Revenue bond—issued by government subdivisions (a category not well defined by the Internal Revenue Service) or by agents on behalf of various institutions, including colleges and universities. If an institution, such as a state university, is prohibited from incurring debt itself, an independent corporation, such as a nonprofit research foundation, may issue revenue bonds on behalf of the institution. Debt is serviced through use charges on the facility being financed. Debt security is limited to the facility. Upon retirement of the debt, title must pass to the institution for whom the bond was issued.

Industrial development bond (IDB)—a type of revenue bond issued by a city or county with no obligation to the taxpayers. IDB's originally were conceived to help depressed areas increase their tax base by attracting industries, but they also can be used to finance purchase of scientific equipment or research facilities. IDB legislation has been enacted by 47 states. The debt is serviced through a direct lease between the municipality and the user, or through a lease to a third party with established credit (such as an independent research foundation) to guarantee payment and manage the debt. Security can be limited to the facility being financed or include additional security offered by the user or by the third party. Upon retirement of the debt, title may pass to the user or to the third party.

Municipal lease—a mechanism that allows government subdivisions to purchase facilities or equipment without officially incurring debt. As opposed to a bond, which is a long-term debt commitment, the term of a lease is on a fiscal-year basis with renewable options. (This allows state universities, barred from incurring debt, to borrow directly because the debt can be canceled.) The lessee must be a government subdivision. Liability on a municipal lease is limited to the terms of the lease, and the rate of payment must include principal and interest. Municipal leases generally conform to Office of Management & Budget Circular A-21 requirements, however, because the lessor is an "arm's length agent" (the lessor cannot control the actions of the lessee) and because the lease can be canceled. Upon retirement of the debt, title must pass to the lessee at completion of nominal payment.

Tax-exempt commercial borrowing—essentially a revolving, unsecured line of credit obtained from a bank. Interest to the lender is tax-exempt because of the nature of the borrower—for example, a tax-exempt, nonprofit research foundation.

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funds, and particularly from individual scientists' contracts and grants.

"The scientific funding mechanism is dominated by the single investigator grant, and that mechanism is clearly failing to provide adequately for instrumentation," according to Cornelius J. Pings, vice provost and professor of chemical engineering at California Institute of Technology and former director of the now disbanded National Commission on Research.

Like Pings, Olson thinks the traditional patterns for funding the purchase of scientific equipment simply haven't worked. "Universities can and must adopt a businesslike approach to equipment financing," he says. "The typical university research administrator refuses to be a risk manager. There is a downside risk in borrowing money to purchase equipment, but even that has advantages because it forces careful evaluation of an investigator's or a project's strength."

Colorado State got involved in debt financing, Olson says, out of necessity. The Colorado State University Research Foundation (CSURF) had been incorporated in 1941 to handle university patents and inventions, and in 1960 it began to handle contracts and grants on a regular basis. In 1966, the university wanted to purchase its first scientific computer, a Control Data Corp. 6400, and to set up a center for disease control laboratory.

"Essentially we were an unknown university, pretty much in the middle of nowhere, in a state not strongly behind basic research," Olson says. The university requested that the state legislature appropriate the \$2 million to \$3 million for the computer and was turned down. The legislature suggested that CSURF finance the project. The research foundation used revenue bonds to raise the money for the computer, as well as \$1.3 million for the center for disease control laboratory.

Since then, CSURF has used a revenue bond to purchase a 200-acre research farm; an industrial development bond to purchase a \$9 million scientific computer for the National Center for Atmospheric Research; municipal leases to purchase several small research computers, a satellite station computer data bank, and two research aircraft; and has established a tax exempt line of commercial credit used to purchase an assortment of research equipment including chemistry instrumentation costing between \$10,000 and \$50,000 each. The foundation is in the process of applying several forms of tax exempt debt financing to raise more than \$30 million for the purchase of a CDC Cyber 205 research computer, the building to house it and the CSU computer science department, and to install a new university telecommunications system.

"We tell our faculty members they can have any piece of equipment they can pay for," Olson says.

Although Olson acknowledges he would rather have cash from traditional funding sources in advance to purchase equipment, he also notes several advantages of debt financing:

- The equipment becomes available to the scientist sooner than if traditional funding were sought and,

Industrial development bond used for research computer

Project	Cray Research Inc. Cray 1 computer for the National Center for Atmospheric Research in Boulder, Colo.
Cost	\$9 million
Terms	10 years at 6% interest in 1977
Issuer	Boulder County, Colorado, for Colorado State University Research Foundation (CSURF)
Authority	State and federal industrial development bond laws
Debt servicing (a third-party lease)	CSURF purchased the computer from Cray Research and leases it to NCAR; rent includes principal and interest; terms include a 90-day cancellation clause
Advantages of third-party lease	Provides additional equity, default management, and tax-exempt financing experience
Title	CSURF, which has agreed to sell the computer to NCAR for \$25 upon retirement of bond

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Olson thinks almost any university could use debt financing to purchase scientific equipment, but he warns that it isn't something to be entered into lightly. "It involves a lot of time and a lot of research," he says. "You need good professional advice. An investment banking firm and good legal tax counsel are essential. We spend a lot on legal advice, but with constantly changing tax laws and regulations it can't be avoided." And, according to Olson, it takes a certain amount of determination. "More than one lawyer told us it simply couldn't be done," he says.

The independent status and professional staff of CSURF also have contributed significantly to the success of the CSU effort. The president of the foundation, Cynthia J. Hanson, and vice president, Ronald B. Kaiser, both have business backgrounds. Besides managing about $30 million (soon to grow to about $60 million) in debt, they manage 13,000 acres of property owned by the foundation, as well as the university's patent and copyright income.

"A good way for a university to get started in this," Hanson says, "is to establish a tax exempt line of commercial credit for small equipment purchases. It is simpler than becoming involved in bond issues or leases." It also helps establish the kinds of cooperation required to evaluate a proposal's chances of success.

One tricky aspect of debt financing equipment is including interest in use charges. Some granting agencies are reluctant to allow it, and Office of Management & Budget Circular A-21 allows it only under certain circumstances. CSU has finessed the problem by, in some cases, writing cancelable leases to satisfy Circular A-21 requirements and, in other cases, paying the interest from other sources of income such as that from patents. But Olson believes that changes should be made in Circular A-21 and in the NSF Grants Manual. "OMB is considering allowing interest charges associated with buildings," he says. "I don't see how equipment is any different."

According to Olson, other universities are becoming interested in the concept. He has held two seminars on the subject, and the most recent attracted representatives from about 30 colleges and universities. Olson says that the University of Wyoming and the University of Utah, among others, plan to try debt financing.

One of those in attendance at the seminar, JoAnn Treat, associate executive director of the Texas A&M Research Foundation, says that Texas A&M is well funded in terms of purchasing facilities but not equipment. The research foundation is looking into debt financing as a way of helping the university alleviate the equipment problems, she says, but because of OMB Circular A-21 requirements, they are not sure it will work.

Charles G. Overberger, vice president for research and chemistry professor at the University of Michigan, also believes the A-21 requirements would cause many universities problems. He also believes that although direct federal funding for equipment purchase is still inadequate, the agencies have made a concerted effort in the past several years to redress the problem. "In terms of equipment we still have problems at Michigan," he says, "but we are in much better shape than we were 10 years ago." Overberger is concerned that at a university the size of Michigan, an inordinate amount of central control would be required to make debt financing work.

Caltech's Pings believes the idea has merit, but he also believes the government must allow interest to be included in use charges. "If interest were allowed," he says, "it would foster development of creative mechanisms to purchase equipment. Government should hold universities to good business practices, but it should not stand in the way of those practices."

But Pings thinks it would be regrettable if debt financing became the only way to purchase equipment. "The government has an ongoing responsibility to provide for instrument procurement," he says. "The mechanisms should be mixed."

Olson agrees. "When we talk to people about this, we emphasize that debt financing isn't the best way to buy equipment. In a way, it is the worst. But in many cases today, it has become the only way to get the equipment you need." □

Mr. Walgren. Mr. MacKay.

Mr. MacKay. If the chairman will yield, that is just too provocative a comment. Perhaps we will never know again what you financed. [Laughter.]

Mr. Walgren. Well, if we never see you again we will have to call and find out what happened.

Well, thank you very much for those statements. Would either of the first two gentlemen like to comment on Dr. Olson's suggestion, and particularly along the idea of how far this could go in satisfactorily meeting the needs.

Dr. Langenberg. I think it could go a long way. I think over the years that I and many of my colleagues have become better and better acquainted with what Dr. Olson has managed to achieve at Colorado State, and we have become progressively more impressed with his results but, as he pointed out, it is not easy.

I noted one aspect of the project that the Interagency Working Group has embarked upon to stimulate university management. That aspect was the promulgation of the faith, if you like. One might ask the question, "To whom?" The intention is to spread the word on such things as creative financing to all of the managers in a university, and those range from bench scientists all the way up to boards of trustees.

I have seen university administrators comment favorably and enthusiastically about Dr. Olson's ideas. I have even seen a few scientists who knew about them comment favorably on them, but I shudder just a little bit to imagine taking a proposal for a major debt financing to a typical university comptroller, a vice president for finance, or a typical university board of trustees. They are quite familiar with doing that to construct new dormitories or classroom buildings or athletic fields, but if you tell them you want them to borrow to buy an electron microscope, I would prefer not to try that without a lot of support from Dr. Olson.

Mr. Walgren. Well, now, let's understand why.

Dr. Langenberg. I think it is a matter of attitude. It is unusual. Everyone knows about buildings and everyone knows about financing buildings, because most people have bought houses. A good many businessmen know about financing equipment and instrumentation but university managers for the most part simply do not.

Would you agree with that, George?

Dr. Olson. Well, we have conducted two national seminars on this subject and they have evoked a lot of interest and a lot of response and enthusiastic attendance, and not a lot of debt financing. It is a complicated business. The tax laws are such that some things work for private universities and do not work for public and vice versa.

You need to be in the business. You need to have people working with you that have a business background, that have been in the business of financing equipment. Industry does this. They buy their equipment on various financing mechanisms.

Mr. Walgren. If I understand it right, then, it is more an attitudinal thing than an actual barrier. When Dr. Langenberg says it isn't easy——

Dr. **Olson**. Well, it's not easy. Maybe in our seminars we do as much to discourage people as encourage them, because we tell them—we do it in conjunction with a good tax counsel, lawyer, and an underwriter to explain all the mechanisms to do this. However, we have demonstrated, I think, through 40 million dollars' worth of scientific paper that the public at large out there is ready and willing to buy this high-risk paper. It is not easy to sell the paper on a Cray computer when it is the second one that has ever been built, or go out for positron emission tomography equipment that people cannot even pronounce. But they have demonstrated a willingness to buy this kind of paper, whether it is lease participation certificates or bonds or what have you. The problem I believe is really in the university administrations.

Mr. **Walgren**. Dr. Kwiram.

Dr. **Kwiram**. Well, I think I commented on this issue from CCR's point of view briefly in my prepared statement. I think it is a creative solution that can be effective in certain circumstances. I think it is indeed complicated. A central issue, of course, is the fact that it does not create new money in one sense. I mean, you have to take it from user's fees or someplace. You have to pay for it. There is a conservation of money law here that comes into play as well.

In addition to that, there are potential difficulties if someone like NCAR were to pull out of a lease, for example, because their direction has changed, and you were to lose a major individual or entity of that sort that is going to be footing the bill through user fees. We try to do some of this in amortizing equipment in our department, and it is not quite a month-by-month problem but almost that kind of a situation where you wonder, "Well, is this guy going to pull out next month? Is he going to lose his grant? Are we going to be able to sustain the program?"

Mr. **Walgren**. Therefore, this goes to the question of whether or not the private sector is willing to put up the money to buy such equipment. Inasmuch as that equipment might become obsolete relatively quickly, there is a real risk there?

Dr. **Olson**. Well, the big risk, as Dr. Kwiram mentioned, is in losing funding. We don't fund everything that our faculty asks for. We tell them that we will buy them anything they can pay for, and it means that a university administrator has to be a risk manager. I don't believe this can be done on a departmental level, although I admire a department that tries that. I think it requires the university resources to look at this problem, and it requires the use of an affiliated organization.

We use a foundation that is not part of the university. It is arm's-length, and it can assume debt and it can stand between the bondholder and a piece of equipment and take action to do something with that equipment. For example, if NCAR—we lease the Cray I computer to NCAR with a 90-day cancellation clause. That didn't make those bonds any easier to sell. However, the bondholders knew that between the NCAR scientists and their standing with the black box was the CSU Research Foundation, who knew who was using supercomputers and where it could be leased or sold.

Therefore, you know, there has to be a businessman's approach to it, and some things you are not going to fund because they are too risky.

Mr. **Walgren**. Is that a substantial limitation with this approach, that some things you would not fund, some instruments you would not fund?

Dr. **Olson**. Oh, you bet. We turn down faculty members all the time who have, you know, one $50,000-a-year grant and they have maybe $5,000 they can use for user equipment, and they want a $1 million solid-state surface chemistry laboratory. It is not going to fly.

I think it does encourage shared use. That is an example where we send the faculty member out and say, If you can get people in physics and electrical engineering to come along with you, maybe we will buy an Auger spectrometer. Then he comes back very enthusiastic, with several other faculty members willing to share in the use and support of that piece of equipment, so it does help us in our shared use concept.

I agree, this is not the best solution. The best solution is for you to give us, you know, $2 or $3 billion. [Laughter.]

Mr. **Walgren**. Why is that a better solution?

Dr. **Olson**. Well, you know, it's a lot of headaches to do this. [Laughter.]

However, if you are not going to give us $2 or $3 billion, then I think this is a solution. It does not create new money but it makes everybody pay his fair share of the bill, including our State projects, the State-funded projects that use a piece of equipment. We have about 20 percent of our research funded by private sources. They pay their fair share for the use of the equipment, as do all the other agencies, the Federal Government.

Dr. **Langenberg**. If I may comment, Mr. Chairman, one of the most attractive features of what Dr. Olson is describing is that it does encourage careful management. If the National Science Foundation, for example, presents to me, a bench scientist, $500,000 to buy an instrument, and I proposed to buy that instrument and I succeeded in the peer review process, I view that instrument as mine.

Now I may use about 100,000 dollars' worth of time on that instrument and my interests may change, and I may do something else. There is nothing whatever to drive me to want to share it, to arrange for others to use it, to manage the rest of the value of the instrument.

What Dr. Olson has been doing is complicated. It is complex. It does involve risk, and it is a little frightening to a lot of people, but it does encourage sound management.

Mr. **Walgren**. Well, then, if I could be permitted just one more question, you recommend that interest on obligations be tax-exempt. Now how much would that contribute to the——

Dr. **Olson**. We use only tax-exempt financing now. I am not asking for something that is going to greatly impact Federal revenues. We have an advantage over private industry. We use tax-exempt revenue bonds, tax-exempt industrial development bonds, tax-exempt municipal lease-purchase agreements, and with an opinion, a tax-exempt line of credit.

What I am saying is that if we did not have to juggle from one to the other, going IDB and having to make all the presentations before a city or county, if it was scientific instrumentation for research or educational purposes, for a college or a university, if that was tax-exempt, our opining attorneys would say, "It meets these requirements and you may issue whatever obligation is appropriate," a lease or a bond, and it would be greatly simplified. I think if it was simpler it would encourage a lot of university administrators to consider this.

Now we like to cite examples like Cray computers and 205's and big things, you know, that cost $9 to $10 million, but this is a very valuable tool for things that cost from $100,000 to $1 million. However, it is complicated. We are working with a private university now in requesting the city in which they are located to create a university equipment fund so they can use the municipal lease-purchase contract route.

Well, you know, the complications of going through all this just to be able to provide equipment for a private university which happens to be a dominant factor in this community, is just a long way around achieving what we have proposed as a modification of section 103 of the Code.

Mr. **Walgren**. I see. Mr. Gregg.

Mr. **Gregg**. Your modification goes a lot further than just being limited to scientific equipment. As I read it, it is for scientific or educational purposes, which means that it could be used for home economic equipment or football equipment or language equipment or any other form of educational purpose equipment, as I read it.

Dr. **Olson**. I am here representing the university and I have a hard time separating research and education.

Mr. **Gregg**. Well, I don't.

Dr. **Olson**. Oh, OK.

Mr. **Gregg**. I think we are interested in scientific issues, not necessarily home economics or football.

Who gets the investment credits that are generated?

Dr. **Olson**. This is not section 38 property, so there is no investment tax credit.

Mr. **Gregg**. Is there any way to set these up today under our present codes so that you can sell them as a limited partnership and——

Dr. **Olson**. There is not because if it is used by a tax-exempt agency, it does not qualify as section 38 property. That is what both the old code and the ERTA 1981 modifications were limited to. We lobbied hard to get the extension of safe harbor leasing, which would have been a great boon to universities 2 years ago. If the safe harbor leasing conditions had been extended to scientific equipment the way it was to commuting equipment, a bus, it would have been a great boon to the acquisition of scientific equipment, but we do not qualify for section 38 property so we are excluded.

Mr. **Gregg**. Well, you could certainly finance it out of the private sector, maybe, if you had the option of selling the investment credits.

Dr. **Olson**. Every financing we have done, we have looked at tax-exempt financing and leveraged leasing. They are very close, if you can take advantage of both investment tax credit and rapid depreciation, but we are not qualified. We can still depreciate but we are not qualified for the ITC.

Mr. GREGG. Some States have a higher education authority which can issue bonds. Is that——

Dr. OLSON. Those are, in effect, the revenue bonds. They are issued on behalf of a State agency, and they are tax-exempt.

Mr. GREGG. They can issue those for equipment.

Dr. OLSON. Yes, sir, they can. The most successful agency for that is in Pennsylvania. The Pennsylvania building authority also finances equipment.

Mr. GREGG. That structure already exists, really. You just want to make it cleaner for——

Dr. OLSON. I would like to make it cleaner and I would like to make it include both public and private institutions, because both contribute substantially to our research health.

Mr. GREGG. Do you have an estimate of what this is going to be in the form of tax expenditures if you put this into place?

Dr. OLSON. I don't——

Mr. GREGG. That is lost revenue.

Dr. OLSON. If we put it in place and we encourage a lot of people to finance this way, maybe we will lose revenue but you won't be financing equipment by billion dollar grants. However, if we encourage people to do what we have done at Colorado State University, and go through all of the mechanisms, the machinations of trying to get the right financing instrument for the right scientific instrument, there is no difference. I am just saying, "Let's simplify it."

Mr. GREGG. However, you are saying, "Let's simplify it so it will be used more," and I guess my question is, if it is used more, how much is it going to cost us vis-a-vis what we are spending on instrumentation today? You probably have not done those figures.

Dr. OLSON. I have no idea of that. You know, either it is going to be appropriated through some Federal agency or we are going to debt finance it. We are not going to get it from our own university funds, and I don't think we are going to get it from an equipment grant program. I do not think there is any alternative, that somehow it is going to cost the people at large.

Mr. GREGG. Well, I have to agree with that.

Dr. Langenberg, can you tell me—you have seen an increase this year of about 60 percent in the instrumentation budget of NSF which you were intimately familiar with before—can you tell me whether you feel that significant increase in funding is being applied properly relative to the different directorates, or whether you think that it should have been applied differently?

Dr. LANGENBERG. On the whole, I think it is. I think the balance, the present balance in the NSF budget with respect to instrumentation, and indeed with respect to most of the rest of it, is quite appropriate.

Mr. GREGG. Thank you very much.

Mr. WALGREN. Thank you, Mr. Gregg. Mr. MacKay.

Mr. MACKAY. Well, I am assuming the subcommittee is looking into this question because we are concerned, a, whether enough money is going into instrumentation and, b, whether it is being skewed to agency needs and whether there is coordination. Dr.

Langenberg, I think you are answering that you think the coordination is there through NSF.

Dr. Langenberg. To a substantial degree. I think the Interagency Working Group has been a reasonably effective means of exchanging information and getting some coordination among agencies. As you probably know, there is a good deal of program-level and higher-level coordination among the agencies of all kinds. There are groups of people in the materials scientists who compare notes frequently to find out what each agency is funding, what their budgetary plans are. There is a good deal of coordination. I do not mean to say that it is perfect. It is far from that, but there is a good deal of it.

Mr. MacKay. Therefore, the risk under our policy today is that if you are doing basic research in an area no Government agency is interested in, you may come up short; and the risk under Dr. Olson's program is, if you are doing basic research in an area where even with a Government subsidy it won't pay for itself, you will come up short.

Dr. Langenberg. Well, I guess I would dispute your first presumption, sir, because given the mission of the National Science Foundation——

Mr. MacKay. I would like to be reassured that my presumption is wrong.

Dr. Langenberg. Given the mission of the National Science Foundation, which is to support the health and vitality of American scientific research across all the scientific disciplines, I find it difficult to think of an area of science in which at least the Foundation is not, in principle, willing to support good——

Mr. MacKay. Well, let me try one: What about research in the areas having to do with accounting, finance, and other areas which formerly were funded by NSF and are not now?

Dr. Langenberg. There is, to the best of my knowledge, no change in the character of the research in economics and in related subjects within the behavioral and social sciences that NSF is funding. There has been a reduction in level, but that reduction in level has not restricted the range of topics that can be supported if sufficiently meritorious.

Mr. MacKay. My understanding is that under either the rhetoric of moving away from applied research and strictly to basic research, or else under a policy decision that said, "We are not going into the science areas any further," those funds are not now available.

Dr. Langenberg. No, I do not think that is correct. There was several years ago a very substantial reduction proposed for funding in the behavioral and social sciences. The intervening several years have seen significant increases in the funding in those areas in the Foundation's budget, not to a level equal to that which existed around 1979 or 1980 yet, but there has been a substantial recovery. As I said, there has been no particular change in the principle. If it is sufficiently meritorious across any field of science, but certainly including the behavioral and social sciences, it can in principle be funded by NSF if funds are available.

Mr. MacKay. I understand that in principle it can. My problem is not with the organic statute. My problem is that the agency has redefined its mission more narrowly than the organic statute.

Dr. Langenberg. I really don't think that is the case. It has not, for example——

Mr. MacKay. Well, I may be erroneous in——

Dr. Langenberg [continuing]. It has not really retreated from applied research. Applied research has, in most times, accounted for a relatively small proportion of the Foundation's total expenditures. It is very difficult to estimate because it is very difficult to judge with any precision whether a particular piece of research is applied or basic, or 60 percent basic, 40 percent applied, or whatever. However, estimates in the range of 10 to 15 percent or so are probably not unreasonable. There has been no retreat from that.

There was, in a reorganization 2 years ago, a change from the mode of funding applied research in programs specifically labeled as applying only to applied research. Rather, the funding is now carried out throughout the research directorates of the Foundation. It covers both basic and applied research and the principal criteria for selecting proposals which will be supported do not have to do with whether or not they are basic or applied, but simply with whether the peer review system says they are meritorious.

Mr. MacKay. Dr. Olson, how would we know under your proposal how much funding we were providing?

Dr. Olson. Well, you wouldn't really know but I think that it is the responsibility of the Congress to fund basic research, and if that basic research budget for the country is healthy and strong and the universities are managing the equipment programs, it is going to be a healthier situation.

For example, one of the agencies on the funding initiatives, when they discussed a reduction in their budget that was requested for the support of research they were told, "You may not touch the $10 million allocated for equipment because there has been such a pressure for that to be held constant." Therefore, they reduced $10 million in other papers. That saved 50 principal investigators at $200,000 apiece that did not get funded. Somebody else made a decision on what research was going to be funded because of an equipment initiative, and I think——

Mr. MacKay. I am just testing the results. The results would be that the investigator would be a kind of an entrepreneurial process of determining what our policy is, a user-friendly process.

Dr. Olson. As far as what equipment——

Mr. MacKay. If you could sell the bonds, the United States would invest in whatever you are——

Dr. Olson. No, no, that is just the reverse. If the U.S. Government invests in that man's science and thinks it is good science, then the university will say, "We will invest in the equipment because the science is good." I hope we would never get to where the guy would say, "I have a university that will buy me this big equipment," and we would support the scientist because he had the equipment and not because he had the scientific program.

Mr. MacKay. When I say you could sell the bonds, I am assuming by that that you would be able to convince the underwriter that some agency or some private sector user was willing to pay for the research.

Dr. OLSON. Correct.

Mr. MACKAY. I am simply saying that we have then delegated to whoever that nameless underwriter is out there, the policy decision about how much we are going to put in it as far as the Government is concerned.

Dr. OLSON. No, not if you fund a basic research program. You are funding $6 billion this year now in total from the Federal Government and some private sources. If we were to buy, as universities, 1 billion dollars worth of equipment, that would cost about 4.5 percent of that budget. You would know. It would be individual project line items as a user charge. About 4.5 percent of that would be going to buy equipment, but the determination of your funding, I think, should be on the basis of good science, period. Then, you know, if we can back the scientist up that is funded with good equipment, we all benefit.

Mr. MACKAY. I guess I am driving at the same thing Mr. Gregg was driving at, and that is, except for the fun and the excitement of going out and locating the money, you would just as soon that we go ahead and appropriate the money, would you not?

Dr. OLSON. Absolutely, you bet. [Laughter.]

Mr. MACKAY. All right. Therefore, what you are suggesting is that we just appropriate it in a way where we don't have to make the decision, if you assume that a tax expenditure which is a deduction is in fact an appropriation of public funds.

Dr. OLSON. If you assume that, yes.

Mr. MACKAY. Do you know of any other assumption as to what it is?

Dr. OLSON. No; I made the statement that the public is going to pay for a public good, and I think basic research is that.

Mr. MACKAY. Oh, I agree, I agree. Your definition would include automobiles for university presidents and financial vice presidents. That is equipment used in education.

Dr. OLSON. Well, I said scientific equipment, but you have to realize that most of the things universities buy today, like football stadiums and what have you, are issued with tax-exempt bonds.

Mr. MACKAY. I disagree with that policy but I agree that that is what is happening, and that is why I am afraid of what you are talking about.

Dr. OLSON. I just want to be treated as well as a football stadium, that's all.

Mr. MACKAY. I agree, and I think we could tighten up the language and perhaps that might help, but what you are suggesting——

Dr. OLSON. I don't call myself a bill writer. No, that could be changed anyway. If it supported research, I said education because it is hard in my mind to separate the two. However, if we made it simpler I think there would be more people debt financing and there would be more sources of research revenue supporting that equipment, and it would not be just the NSF budget or the DOD budget. It needs to be made simpler and clearer cut for the university administrator.

Mr. MACKAY. I don't mean to be coming across as belligerent.

Dr. **Olson**. Well, I don't either.

Mr. **MacKay**. I admire anyone who is innovative enough. Thus far, what you have testified is, we have already funded $20 million for you that we didn't know about.

Dr. **Olson**. That is right, $40 million, yes.

Mr. **MacKay**. Therefore, we are helping you.

Dr. **Olson**. Thank you.

Mr. **Walgren**. Thank you very much, Mr. McKay.

Can I just get a quick reaction to whether or not the Congress should be requiring a certain percentage of NSF moneys to be used for instrumentation and address it to Dr. Langenberg?

Dr. **Langenberg**. I would prefer not to see you specify a proportion. You will find that if you look at the NSF budget that you have had proposed to you for fiscal 1984, that the proportions of the total budget specified for instrumentation range very widely. As Dr. Knapp pointed out, in some parts of the Foundation they range up to 20 percent. In other parts, as you can imagine, in the behavioral and social sciences the instrumentation costs are quite low, although computers are required.

I think I would prefer to see a somewhat lighter hand expressed in a continuing, gentle but very persistent interest on the part of this subcommittee in whether or not instrumentation is being funded adequately.

Mr. **Walgren**. I see. There is one other thought about how these numbers of $136 million tie to the numbers that Dr. Keyworth indicated were being spent, increases on instrumentation. I wonder if you are familiar with his indication from the Office of Science and Technology Policy that there are $384 million in, I guess, 1984 dollars. Do you know whether your $136 million ties with Dr. Keyworth's $384 million?

Dr. **Langenberg**. I have no idea what the connection is, since I don't know where that $400 million came from. I might speculate that it might include, for example, some of the major facility initiatives which have been expressed in the Department of Energy budget, for example, construction of the linear collider at Stanford and things of that sort.

Mr. **Walgren**. Maybe we can give you these numbers and you could just comment briefly on them.

Dr. **Langenberg**. OK, I would be happy to do that.

Mr. **Walgren**. Well, gentlemen, thank you very much. I am sorry we are running so late. Those were most interesting presentations from all of you.

The last panel is made up of industry representatives: Dr. Gerald Mantell, the director of corporate analytical services of Air Products and Chemicals Co., and Dr. Frederick Darnell, the director of basic research for the Dupont Co.

Gentlemen, we are pleased you are here with us. Your written statements will be made part of the record. Please summarize as you feel comfortable. Shall we start with Dr. Mantell?

STATEMENT OF GERALD J. MANTELL, ASSOCIATE DIRECTOR, CORPORATE RESEARCH SERVICES DEPARTMENT, AIR PRODUCTS & CHEMICALS, INC.

Dr. MANTELL. Thank you, Mr. Chairman. I wish to thank you for this opportunity to testify. I will submit my prepared statement for the record.

My testimony will provide specific examples of a number of mutually-beneficial instrument sharing arrangements between Air Products and a neighboring university. I will address also instrument needs of undergraduate schools in our area.

Our instrument arrangements were of several different types. In one, we helped set up a modern instrument laboratory and we operated it jointly with the university. In another case, graduate students from the university use instruments in our laboratory and consult with our expert; and in a third instance, the university was able to leverage our contribution toward partial payment of an instrument to obtain immediate delivery of the instrument and its full use.

Now each of these arrangements required people on both sides who believed in and supported what we were doing. Some of the arrangements involved complex negotiations and signficant amounts of personnel time.

In the course of contacts with colleges and the university in our area, we have learned firsthand that instrumental needs go far beyond what industry can reasonably handle. This point has been made several times today and need not be elaborated on further. However, I could mention that our company has limited budgets, has limited human resources, and these special arrangements with universities are limited to those projects that are in line with our mission and our own interests.

Now to describing some of these special arrangements: Lehigh University is a neighbor of ours in the Lehigh Valley. In October 1977 Lehigh and Air Products decided to set up a mass spectrometry laboratory at the university. We selected a suitable instrument costing $150,000. We each paid $75,000 and allowed Lehigh to hold title to the instrument. We set up operating procedures and a formula for sharing costs based on usage of the laboratory. Both partners then had a laboratory at less than the cost of two separate laboratories, a clear benefit to both parties.

At that time Air Products could not justify setting up its own internal laboratory. We were only able to take this step when our use of the Lehigh instrument had reached a significantly high level. At present we are not using the Lehigh instrument but our ties with the university, professional and otherwise, in this area are very strong, and we are planning on a joint longer-range program in mass spectrometry in the near future.

The second program had its start 1 year ago when a professor from Lehigh University called to suggest a joint program in emulsion polymers. In this case, the instrument—a nuclear magnetic resonance spectrometer, which you have heard about several times today—was in our laboratory, and so was the expert in its use. After much discussion, the joint program was launched in October 1982. Two graduate students visit our laboratories once a week with samples of polymers prepared in their graduate program. Our NMR experts help them obtain NMR spectra and interpret instrument data.

The benefits to the university are clear: The graduate students have access to an instrument that the university cannot afford, and in addition they are learning much from our NMR expert. There are some benefits to us, too. Our expert is stimulated by the professional interactions with the students and their professor, and R&D people in our laboratories who are working in the polymer field have great interest in this program.

Mr. WALGREN. If I could just stop you there, I am sorry but I am going to have to excuse myself. I want to ask Mr. MacKay to take the Chair. I don't want my silent exit to indicate any lack of weight to your testimony. We are most interested in this and I do, on behalf of the committee, want to express my appreciation to both of you for coming. Now I will excuse myself. Thank you.

Dr. MANTELL. The third example, Air Products decided to donate $50,000 to Lehigh University for instrument purchases. This was part of a commitment that we have as a member of the council for Chemical Research, which was described earlier.

After several discussions with the chemistry department chairman, we contributed $25,000 for an instrument to a laboratory, an existing laboratory at the university, one that we use quite often, and another $25,000 toward purchase of a high-resolution laser diode infrared spectrometer. There are probably no more than 50 to 100 such instruments throughout the world, and there were none in our area at that time.

What happened next was rather interesting. Our contribution was only 30 percent of the cost of the instrument. Lehigh worked out a special deal with the vendor and obtained immediate delivery. In exchange, the professor in charge of the instrument at Lehigh is doing computer software development for this vendor.

This same vendor—and this is an interesting part of this story—several years ago had an arrangement with Ohio University to work out some special problems with this early model. A graduate student involved in this project at Ohio University is now on our staff, so we will have an excellent liaison person with Lehigh University in planning a joint program using this instrument, which is what we intend to do.

I wish to turn now to some information about undergraduate schools. I believe it important that we not overlook instrument needs of undergraduate schools in our efforts to help graduate programs. We donated a fully depreciated NMR instrument to Lehigh last fall. It was just what they needed for their undergraduate organic chemistry programs, and in addition saved $35,000.

It is rather interesting, too, in line with what we have heard before, that a more advanced, computer-driven instrument would not have been useful here because the students need hands-on experience. A similar instrument was given to Muhlenberg College, also a neighbor in our valley. Two other colleges in our area, Lafayette College and Cedar Crest College for Women, have informed us of specific instrument needs. Incidentally, these instrument needs are not the high-powered instruments that you have been hearing about today. They are rather simple instruments. In these cases at the moment we can provide little or no help.

Discussions with faculty members from these institutions indicate that the problem is getting worse, not better. They have fewer funds than in prior years. Instruments become obsolete faster, as you have heard, and they are costing more, which you have also heard.

In closing, I would like to emphasize the importance of universities having up-to-date instrumentation. First, we need skilled graduates, trained on state-of-the-art instrumentation. We want and need newly hired graduate students to bring with them up-to-date technology when they join our company. I think it was Dr. Kwiran who really addressed the importance of this technology transfer. In a sense, this is what we are concerned with here.

Second, and related to the first point, universities are where basic research on instruments is done and where next-generation instruments are often developed.

Last, it is important that the universities be supported to establish centers of educational excellence in science and technology. You have heard this before, too. We face tough competition from abroad and foreign companies. We are indeed in a race for technological superiority and excellence which I believe we cannot afford to lose.

Thank you.

[The prepared statement of Dr. Mantell follows:]

TESTIMONY FOR COMMITTEE ON SCIENCE & TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVE HEARINGS - 8 March 1983

TESTIMONY FROM GERALD J. MANTELL, ASSOCIATE DIRECTOR, CORPORATE
RESEARCH SERVICES DEPARTMENT, AIR PRODUCTS & CHEMICALS, INC.,
TREXLERTOWN, PA

MR. CHAIRMAN,

I AM PLEASED TO BE HERE AND WISH TO THANK YOU FOR THIS OPPORTUNITY TO PRESENT MY TESTIMONY. WITH YOUR CONSENT, I WOULD LIKE TO SUBMIT MY PREPARED STATEMENT FOR THE RECORD.

AS DR. KWIRAM INDICATED, MY TESTIMONY WILL PROVIDE SPECIFIC EXAMPLES OF A NUMBER OF MUTUALLY BENEFICIAL INSTRUMENT SHARING ARRANGEMENTS BETWEEN AIR PRODUCTS AND A NEIGHBORING UNIVERSITY. I WILL ADDRESS ALSO INSTRUMENT NEEDS OF UNDERGRADUATE SCHOOLS IN OUR AREA.

OUR INSTRUMENT ARRANGEMENTS WERE OF SEVERAL DIFFERENT TYPES. IN ONE, WE HELPED SET UP A MODERN INSTRUMENT LABORATORY AT THE UNIVERSITY AND OPERATED IT JOINTLY. IN ANOTHER CASE, GRADUATE STUDENTS FROM THE UNIVERSITY USE INSTRUMENTS IN OUR LABORATORY AND CONSULT WITH OUR EXPERT. IN A THIRD INSTANCE, THE UNIVERSITY WAS ABLE TO LEVERAGE OUR CONTRIBUTION FOR PARTIAL PAYMENT OF AN INSTRUMENT TO OBTAIN IMMEDIATE DELIVERY AND FULL USE OF THE INSTRUMENT.

EACH OF THESE ARRANGEMENTS REQUIRED PEOPLE ON BOTH SIDES WHO BELIEVED IN AND SUPPORTED WHAT WE WERE DOING. SOME OF THESE ARRANGEMENTS INVOLVED COMPLEX NEGOTIATIONS AND SIGNIFICANT AMOUNTS OF PERSONNEL TIME. IN THE COURSE OF OUR CONTACTS WITH COLLEGES AND THE UNIVERSITY IN OUR AREA, WE

HAVE LEARNED FIRST HAND THAT INSTRUMENTAL NEEDS GO FAR BEYOND WHAT INDUSTRY CAN REASONABLY HANDLE. I WOULD NOT WANT TO LEAVE THE IMPRESSION FROM OUR FEW SUCCESSFUL ARRANGEMENTS THAT INDUSTRY CAN FILL ALL THE NEEDS THAT EXIST. OUR COMPANY FOR EXAMPLE, HAS LIMITED BUDGETS, LIMITED HUMAN RESOURCES AND ARE LIMITED TO THOSE SPECIAL PROJECTS WITH UNIVERSITIES THAT ARE IN LINE WITH OUR MISSION AND INTERESTS.

NOW TO OUR SPECIAL ARRANGEMENTS. LEHIGH UNIVERSITY IS OUR NEIGHBOR IN THE LEHIGH VALLEY. IN OCTOBER, 1977, LEHIGH AND AIR PRODUCTS DECIDED TO SET UP A MASS SPECTROMETRY LABORATORY AT THE UNIVERSITY. WE SELECTED A SUITABLE INSTRUMENT COSTING $150,000. EACH PAID $75,000 WITH LEHIGH HOLDING TITLE TO THE INSTRUMENT. WE SET UP OPERATING PROCEDURES AND A FORMULA FOR SHARING COSTS. BOTH PARTNERS THEN HAD A LABORATORY AT LESS THAN THE COST OF TWO SEPARATE LABORATORIES--A CLEAR BENEFIT TO BOTH PARTIES. AT THAT TIME, AIR PRODUCTS COULD NOT JUSTIFY SETTING UP ITS OWN INTERNAL LABORATORY. WE WERE ONLY ABLE TO TAKE THIS STEP WHEN OUR USE OF THE INSTRUMENT AT LEHIGH REACHED A SIGNIFICANTLY HIGH LEVEL. AT PRESENT, WE ARE NOT USING THE LEHIGH INSTRUMENT BUT OUR MUTUAL INTERESTS AND PROFESSIONAL TIES IN THIS FIELD CONTINUE TO REMAIN VERY STRONG. WE ARE CONSIDERING OTHER JOINT LONGER RANGE PROGRAMS IN MASS SPECTROMETRY.

THE SECOND PROGRAM HAD ITS START ONE YEAR AGO WHEN A MEMBER OF THE LEHIGH UNIVERSITY STAFF SUGGESTED A JOINT PROGRAM ON EMULSION POLYMERS. IN THIS CASE THE INSTRUMENT, A NUCLEAR MAGNETIC RESONANCE SPECTROMETER, WAS IN OUR LABORATORY AND SO WAS THE EXPERT IN ITS USE. AFTER MUCH DISCUSSION, THE JOINT PROGRAM WAS LAUNCHED IN OCTOBER, 1982. TWO GRADUATE STUDENTS VISIT

OUR LABORATORIES ONCE A WEEK WITH POLYMERS PREPARED IN THEIR GRADUATE PROGRAMS. OUR NMR EXPERT HELPS THEM OBTAIN SPECTRA AND INTERPRET INSTRUMENT DATA. BENEFITS TO THE UNIVERSITY ARE CLEAR. STUDENTS HAVE ACCESS TO AN INSTRUMENT THAT THE UNIVERSITY CANNOT AFFORD, AND THEY ARE LEARNING MUCH FROM OUR NMR EXPERT. WE BENEFIT ALSO--OUR EXPERT IS STIMULATED BY THE PROFESSIONAL INTERACTIONS. IN ADDITION, OUR R&D PEOPLE ACTIVE IN THE POLYMER FIELD ARE INTERESTED IN THE BASIC RESEARCH DONE BY THE GRADUATE STUDENTS.

IN OUR THIRD CASE, AIR PRODUCTS DECIDED TO DONATE $50,000 TO LEHIGH UNIVERSITY FOR INSTRUMENT PURCHASES, AS PART OF OUR COMMITMENT AS A MEMBER OF THE COUNCIL FOR CHEMICAL RESEARCH. AFTER SEVERAL DISCUSSIONS WITH THE CHEMISTRY DEPARTMENT CHAIRMAN, WE CONTRIBUTED $25,000 TOWARD PURCHASE OF AN INSTRUMENT FOR AN EXISTING INSTRUMENT LABORATORY AT THE UNIVERSITY AND $25,000 TOWARD PURCHASE OF A NEW HIGH RESOLUTION LASER DIODE INFRARED SPECTROMETER. THERE ARE PROBABLY NO MORE THAN 50-100 SUCH INSTRUMENTS IN THE WORLD TODAY AND THERE WERE NONE IN OUR AREA.

WHAT HAPPENED NEXT IS RATHER INTERESTING. OUR CONTRIBUTION WAS ONLY 30% OF THE INSTRUMENT COST. LEHIGH WORKED OUT A SPECIAL DEAL WITH THE INSTRUMENT VENDOR WHO MADE IMMEDIATE DELIVERY. IN EXCHANGE, THE PROFESSOR IN CHARGE OF THE INSTRUMENT WILL DEVELOP COMPUTER SOFTWARE FOR THE VENDOR. THIS SAME VENDOR SEVERAL YEARS AGO, HAD AN ARRANGEMENT WITH OHIO UNIVERSITY TO WORK OUT SOME PROBLEMS WITH AN EARLY MODEL OF THIS INSTRUMENT. A GRADUATE STUDENT INVOLVED IN THIS PROJECT AT OHIO UNIVERSITY IS NOW WORKING AT AIR PRODUCTS. HE WILL SERVE AS AN EXCELLENT

LIAISON PERSON WITH LEHIGH UNIVERSITY IN PLANNING A JOINT PROGRAM USING THIS INSTRUMENT.

I WILL TURN NOW TO SOME INFORMATION ABOUT UNDERGRADUATE SCHOOLS. I BELIEVE IT IMPORTANT THAT WE NOT OVERLOOK INSTRUMENT NEEDS OF UNDERGRADUATE SCHOOLS IN OUR EFFORTS TO HELP GRADUATE PROGRAMS. WE DONATED A FULLY DEPRECIATED NMR INSTRUMENT TO LEHIGH LAST FALL. IT WAS JUST WHAT THEY NEEDED FOR UNDERGRADUATE PROGRAMS AND SAVED THEM $35,000. A MORE ADVANCED COMPUTER DRIVEN INSTRUMENT WOULD NOT HAVE BEEN USEFUL HERE BECAUSE THE STUDENTS NEED HANDS-ON EXPERIENCE. A SIMILAR INSTRUMENT WAS GIVEN TO MUHLENBERG COLLEGE, A NEIGHBOR IN OUR VALLEY. TWO OTHER COLLEGES IN OUR AREA, LAFAYETTE COLLEGE AND CEDAR CREST COLLEGE FOR WOMEN HAVE INFORMED US OF SPECIFIC INSTRUMENT NEEDS. IN THESE CASES, WE CAN PROVIDE LITTLE OR NO HELP AT THIS TIME. DISCUSSIONS WITH FACULTY MEMBERS FROM OUR NEIGHBORING INSTITUTIONS INDICATE THAT THE PROBLEM IS GETTING WORSE. THEY HAVE FEWER FUNDS THAN IN PRIOR YEARS, INSTRUMENTS BECOME OBSOLETE FASTER AND COST MORE.

IN CLOSING, I WOULD LIKE TO EMPHASIZE THE IMPORTANCE OF UNIVERSITIES HAVING UP-TO-DATE INSTRUMENTATION. FIRST, WE NEED SKILLED GRADUATES TRAINED ON STATE-OF-THE-ART INSTRUMENTATION. WE WANT AND NEED NEWLY HIRED GRADUATE STUDENTS TO BRING WITH THEM UP-TO-DATE TECHNOLOGIES WHEN THEY JOIN OUR COMPANY. SECONDLY, AND RELATED TO THE FIRST POINT, UNIVERSITIES ARE WHERE BASIC RESEARCH ON INSTRUMENTS IS DONE AND WHERE NEXT GENERATION INSTRUMENTS ARE OFTEN DEVELOPED. LASTLY, IT IS IMPORTANT THAT THE UNIVERSITIES BE SUPPORTED TO ESTABLISH CENTERS OF EDUCATIONAL EXCELLENCE IN SCIENCE AND TECHNOLOGY THAT SERVE OUR NATIONAL INTERESTS. WE FACE TOUGH COMPETITION FROM FOREIGN COMPANIES. WE ARE IN A RACE FOR TECHNOLOGICAL SUPERIORITY AND EXCELLENCE THAT I BELIEVE WE CANNOT AFFORD TO LOSE.

Mr. MacKay [acting chairman]. Thank you, Dr. Mantell. Dr. Darnell.

STATEMENT OF DR. FREDERICK J. DARNELL, ASSOCIATE DIRECTOR, ADMINISTRATION, RESEARCH DIVISION, CENTRAL RESEARCH AND DEVELOPMENT DEPARTMENT, E. I. du PONT de NEMOURS & CO.

Dr. Darnell. Mr. Chairman, I would like to leave my written testimony as part of the record and just summarize briefly what I consider the main points.

The first ones are on instrumentation. Modern instrumentation is critical to research. It gives us productivity; it gives us new information. Without it, we are not at the forefront of research.

Second, it is expensive. We budgeted this year about 14 percent of our total budget in our research division, du Pont's corporate research lab, for capital equipment—that is, anything over $500 but excluding building—and that has been going up as a percentage steadily. Now that is in the ball park that we are talking about for NSF funding. More importantly, this amounts to over $20,000 per researcher, which I think is much larger than you would find in the universities. Their situation is different, but it is a large amount of equipment every year. We think we are staying up at the front.

Third, we agree, from people who we recruit, from our interactions with consultants and others, that the universities are falling behind, a serious problem.

In the second area, industry contributions, du Pont has two major programs. One is corporate aid to education. This is $10.6 million in 1983. It is unrestricted grants, mainly at the departmental level; chemistry, engineering, life sciences, and finances are the main areas.

Our experience is that these unrestricted grants are much more effective than trying to target it for equipment or buildings or young faculty or something of that sort, and it turns out that it gets used over and over because somebody uses it and then refinances and uses it again. We feel that this directed process—that is, where we choose the department—is the way we get the most effort but the unrestricted part is the way that they can most effectively use it.

The other program is grants and contracts, which amounts to a little over $4 million. These are more specific. They often have the flavor of some of these interactions that we have heard about where we fund, generally still in a block grant but toward a specific area, and where we often ask for patent rights or some other output other than just the science or education that result.

We feel these are very effective ways of going but they are limited. I do not see for du Pont, and I haven't heard anybody else speaking for the rest of industry seeing any large increases in the cards in this area. At the present level it is only a very small contribution to the total deficit in instrumentation.

Third, the other approaches, from my point of view—three comments—block funding or larger amounts aimed at universities and giving them the responsibility for balancing the personnel, versus leased versus bought, capital, et cetera, is the way we would do it. I would not have said it first but Olson said he would like to see the universities doing things in a more businesslike way. Nobody gives us $1 billion for equipment, so we have to figure out how to finance it within our operations, and it comes out of the total dollars. It does not come as an extra on top of operating expenses. The creative financing things, therefore, look like a significant part of the possible things that universities should and can do.

Finally, I think there is—reaching a critical problem in instrumentation—the NSF initiative to increase significantly the funds for that, even though it may be a short-term attempt. This is a significant part of a overall solution which in the long run should be handled in different ways.

[The prepared statement of Dr. Darnell follows:]

TESTIMONY BEFORE THE
SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

Dr. Frederick J. Darnell
Associate Director, Administration, Research Division
Central Research & Development Department
E. I. du Pont de Nemours & Company
Wilmington, Delaware

Mr. Chairman and Members of the Committee:

I am pleased to be able to present an industrial point of view on the problem of obsolete research instrumentation in our universities. I will describe the contributions that Du Pont makes to help in this area, and second other approaches that academia, industry, and government could further consider. Our experience in a corporate laboratory will be offered for perspective on the instrumentation needs of research.

My laboratory carries out a major portion of Du Pont's exploratory research in chemistry, physics, and biology. We have a staff of over 350 technical personnel, an operating budget of $68 million for 1983, and a capital budget over $10 million.

A critical factor in the funding of research activities in general has been rapid increases in the costs of instrumentation relative to other costs. As a result, the

Research Division of our Central Research and Development Department has found it necessary to substantially increase the funds allocated to instrument-related capital expenses as a percentage of total research costs. While researchers in the past often built much of their experimental apparatus, the complexity of modern equipment usually precludes this approach, and equipment must be purchased. Over the past four years we have allocated over 12% of our total research costs to instrument-related capital costs. Moreover, this percentage has been steadily increasing over the period. Of the capital allocation, approximately a third has been used in the purchase of major new instruments costing over $50 thousand dollars.

We spend these large amounts on state-of-the-art instrumentation for several reasons. Enhanced productivity is one, often related to automation and data processing capabilities. Development of new more detailed information is another, which may provide the basis for process control or new synthetic techniques. Instrumentation for leading-edge research is complex, expensive, and usually oriented toward particular experiments; it is hard to accommodate more than one or a few users on a particular instrument.

The Ad Hoc Working Committee report referenced below shows capital allocation of 9% for Xerox, and an average over several years of 8% for EXXON.

Many of those involved in the funding process for university research are planning for capital expenditures at these levels, and the National Science Foundation budget places particular emphasis on providing instrumentation capital, with allocation of 14% projected for fiscal year 84. The Department of Defense also has supported increased capital budgets. We applaud these efforts and hope that they will continue.

Another measure of equipment and instrumentation support is the capital expended per scientist on a yearly basis. Here our Research Division currently spends about $20 thousand per scientist, the amount having grown steadily even in constant dollars over the last few years. I expect this is a larger per capita expenditure than is characteristic of the universities. Certainly the purposes and personnel structures of industry and academia are different, but I believe that a larger number of researchers in the latter are dependent on a given dollar amount of equipment.

The Du Pont Company is very concerned about the problem of instrument obsolescence in university laboratories and the resulting short- and long-term impact on the quality of university research and graduate training. In addition to the research-related values of up-to-date instrumentation noted above, the universities require modern equipment in order to effectively train scientists, whether for academic, industrial or government career. The universities also importantly develop new techniques based on new instrument capabilities. These have been particularly important in analytical chemistry where NSF funding has been most important.

The problem is a serious and complex one with no complete answer at hand. An important step in reaching a solution is increased collaboration and exchange of ideas between industry and academia. A major thrust in this direction was the Ad Hoc Working Group on Scientific Instrumentation, under the auspices of the National Research Council. In general, we support their conclusions, as presented in the report "Revitalizing Laboratory Instrumentation" and feel that efforts to implement their proposals will be beneficial. Support for this important aspect of academic research is critical since it provides the basis for the continued advancement of technology and its application to the needs of society. Nevertheless, with finite resources, industry must be selective in its contributions and support of academic research.

The Du Pont Company engages in several activities relevant to the issue of instrument obsolescence in university laboratories. We were the first industrial corporation to formally institute a corporate aid program to assist in the support of higher education in science and engineering. Our Corporate Educational Aid Program in 1983 will total $10.4 million in unrestricted grants to selected academic units normally at the departmental level in support of research and education in science, engineering, and related fields. While these grants are unrestricted, a survey of recent recipients showed that more than fifty percent were used in part or entirely for capital equipment.

Another significant source of research support for the universities comes from specific research grants to support university research programs of mutual interest. Du Pont grants and contracts for university research totaled over $4 million in 1981 and continue at a comparable level.

These academic support programs represent an important fraction of Du Pont's discretionary dollars, and their allocation requires compromise among a number of worthy objectives. Large increases in the amounts are not anticipated.

During the past decade, corporate aid to higher education has increased more rapidly than any other voluntary source of support. In the 1981-82 academic year corporations contributed $880 million in direct grants to colleges and universities (18% of total voluntary giving to higher education), up from $275 million (13.6%) in 1971-72. Assuming optimistically that half of this aid were for support of science and engineering programs and that 10% of the funds are used for research and instructional instrumentation, a funding of only $45 million dollars would be estimated. While a significant contribution, this sum is small in comparison to the billion or more dollars identified by NSF as needed to alleviate the instrument obsolescence problem. Since the actual figure for corporate aid used for instrumentation support is probably lower than $15 million, even increases in such aid by a factor of two will not provide an adequate answer to the problem.

A recognized, though admittedly partial, solution to the research instrumentation problem in our universities is to permit the expansion of the equipment and donation programs sponsored by industry. Du Pont participates in such a program though the dollar value of this aid is relatively small (less than $100 thousand/yr. in fair market value) in comparison to our other aid programs. The lack of a significant tax incentive appears to be a major barrier for most companies to substantially increase this form of aid. The Economic Recovery Tax Act of 1981 provides for a tax credit on donated equipment equal to the book value (initial cost less accumulated depreciation). However, this book value is based on a depreciation to zero value over only three years. The financial incentive for donation of used equipment would be significantly increased if fair market value were allowed as the tax credit basis.

Based on industrial experience, block funding provides a rational framework for long term solution of the instrumentation problem. By this I mean funding of university departments or large research groups with a total grant based on strength of programs, personnel and other criteria. The burden is then on the recipient department to establish priorities, plan for operating and capital expenditures, consider additional funding sources, and allocate grant dollars accordingly. There are difficulties here both for funding agencies and universities, but it puts responsibility for balanced assessment of needs and priorities with the user.

Of the other approaches proposed by the Ad Hoc Working group for solving the research instrumentation problem, one that appears especially promising is use of creative financing techniques to supplement existing grant and donation sources. Colorado State University has used various tax-exempt debt financing arrangements for the purchase of major research instruments. While such arrangements may not be feasible for every university, they should at least be examined for their potential impact.

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Mr. **MacKay**. Thank you, Dr. Darnell.

You are saying basically that if you were sitting on our side of the table trying to make decisions about policy, you would not target the grants specifically to instrumentation but would leave more flexibility than that, and target it specifically to program?

Dr. **Darnell**. On a short-term basis I think there is a need in instrumentation. On a longer term basis I think it would be better to say, "You are going to do this research. Here is the money for you. You figure out how to spend it right and then report back what you got out of it."

Mr. **MacKay**. All right.

Mr. Gregg.

Mr. **Gregg**. I have no questions.

Mr. **MacKay**. You had some comment about the investment tax credit and also the use of fair market value as the basis. Would that and other type tax incentives substantially increase industry support, do you think?

Dr. **Darnell**. They would increase it. It is a little hard to measure how much. Du Pont does not make a lot of the instruments that would go into education and research, so new instruments is not likely to be a big one for du Pont or much of the chemical industry. It should be for computers and some other areas.

The used equipment one, I think, would contribute to a larger measure, just the sort of thing that Dr. Mantell was talking about.

Mr. **MacKay**. I would also be concerned—and your comments sort of seemed to me to be a sensible approach to this concern—I would be concerned that financial aid for graduate students is part of this same equation. The equipment is part. You can make the same case that there are inadequacies in other aspects of it, and it would seem to me that a better approach to research would be to look at it functionally and try to see what part the Federal Government should play in the overall research picture and then what part private industry should play, and what part the universities should have responsibility for.

I am not sure you are the right person to be asking this question to but I am pleased to hear you, as a private sector person, say that the less restrictive approaches would be better. Would either of you care to comment, in your dealings with universities, do you feel that they have taken a businesslike approach, and have you been satisfied with your output from them? I guess that is the best way to ask that question.

Dr. **Mantell**. I don't think I could really comment on their businesslike approach. The products from universities, their students, are highly skilled people. All the better, if they are more skilled and better trained. The work they do and report is also vital to us.

Dr. **Darnell**. I see them using the funds they have effectively, but I don't think they have sought these other, unfamiliar, creative financing areas. Part of that has to do with the structure of universities and the independence of the individual investigators and departments. It is a difficult job to make it happen even in an industrial, hierarchical setting.

Mr. **MacKay**. Dr. Maxwell points out that in some ways the problem we have now is that grant money has been given to universities over the years, and perhaps because they have tried to stretch it too far or perhaps because there simply has been inadequate money, the money has gone to other places than instrumentation. It has gone more to people, which is tending to have this institution react by being more restrictive now.

Dr. MANTELL. It may be that part of the problem is that universities do not have enough money for skilled people to teach and do research on instruments as well as to buy, maintain, operate and upgrade instruments as they become obsolete. The upgrading of instruments by professors reduces valuable time available for research and teaching. For example, I was speaking to a university professor at Lehigh who had just received a contribution of an old instrument from a large company. He explained that he would have to devote considerable time and some money to put it into a serviceable condition.

This is a case where the university is using valuable manpower instead of capital. This is, in a sense, a productivity issue where output is measured by quality of students and research. Fixing and upgrading old instruments may not be the most productive way to utilize our skilled human resources.

Dr. DARNELL. There is another answer, I think, that Dr. Langenberg or Dr. Kwiram could do better than I can, but what I hear them saying is that the strings that are attached to grants, whether NSF or other, restrain them from going out and putting big dollars into shared equipment. It is much easier to spend it if it is solely for your project, and that sort of rules out large equipment that is shared. That is a much harder problem, so they manage what they can manage and they don't try to solve some of these big problems that are much tougher.

Mr. MACKAY. I guess, Dr. Olson, your comment to that would be that by using an independent, arm's-length, nonprofit foundation as the intermediary, you can get around some of that.

Dr. OLSON. Yes, you can.

Mr. MACKAY. I just feel a frustration that we come back to these questions at times when it appears that our competition is getting ahead of us. What we need to do is to develop some way to find competitors every year instead of every 15 years, and in the long run it would probably be much less expensive. I can feel a major push in this area coming on, you know, because it appears that we are behind again, all the way from science education to research and instrumentation.

Well, I would like to express the appreciation of the committee, which at this point is me, for your coming here. This testimony is very helpful to us in trying to get a handle on what the policy should be as we start into another round of this. Perhaps we can learn from some of the mistakes of the past and develop a program that provides more flexibility and you can spend more time doing what you are supposed to do, and less time trying to figure out how to beat the various hurdles that have been put into the system.

Thank you very much for being here.

[Whereupon, at 4:50 p.m., the subcommittee adjourned.]

1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MARCH 10, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:45 a.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Dymally, Valentine, Reid, Boucher, and Sensenbrenner.

Mr. Walgren. Let me call the subcommittee to order.

Today, the Subcommittee on Science, Research and Technology turns its attention to the National Science Foundation budget proposals for the directorates of biological, behavior, and social sciences and scientific, technological, and international affairs. Witnesses from the National Science Foundation as well as panels of distinguished individuals will comment on the Foundation's plans for the coming year in these areas as well as offer their views on the proposed management and policy changes for NSF.

The NSF budget proposal for fiscal year 1984 earmarks $223.6 million for the BBS Directorate, an increase of $33 million over fiscal year 1983. Much of this increase will go toward activities in the areas of physiology, cellular, and molecular biology and biotic systems and resources. The rest of the increase will be spread among activities in the areas of behavioral and neural sciences as well as social and economic sciences and information science and technology.

Unfortunately, despite these increases we still do not see the funding base restored for the behavioral, social, economic and information sciences despite directives from all of the involved committees of Congress to the contrary. I expect we will explore this further after the Foundation has testified.

The second part of our hearing today will focus on the activities of the Directorate of scientific, technological, and international affairs. The Foundation has proposed a reduction of funding for STIA as well as a change in policy and management in the areas of international cooperative scientific activities, research initiation and improvement and others. I must say at this point that I am most concerned by the policy implications of what is suggested as merely management directives.

We have to view them as more than simply that. I know the committee members will be interested in looking at this very closely.

The BBS and STIA activities are directly involved with the application of technology to our lives, our society, our government, and the world around us. Thus, BBS and STIA deserve our close attention.

We look forward to today's witnesses and their discussion of these important areas. We will hear from Dr. Knapp, Director of the National Science Foundation first. Welcome, Dr. Knapp.

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. EUGENE COTA-ROBLES, PROVOST OF CROWN COLLEGE AND PROFESSOR, UNIVERSITY OF CALIFORNIA, SANTA CRUZ, MEMBER OF THE NATIONAL SCIENCE BOARD

Mr. WALGREN. We are pleased to have you here, Dr. Knapp. Would the other members like to make opening comments or observations?

Mr. VALENTINE. I do not, Mr. Chairman.

Mr. REID. No, thank you.

Mr. WALGREN. Then we will proceed with Dr. Knapp, accompanied by Dr. Cota-Robles. Your written statement will be made part of the record, as usual, Dr. Knapp. Please summarize or proceed as you feel best to communicate to the committee.

Dr. KNAPP. Thank you, Mr. Chairman.

Members of the committee, I am glad to be with you today for the last day of hearings before your committee on the fiscal year 1984 authorization of the National Science Foundation. With me is Dr. Eugene H. Cota-Robles. He is provost of Crown College and professor of biology, University of California at Santa Cruz, and a member of the National Science Board.

The Foundation's fiscal year 1984 budget request proposes important changes in the way in which the NSF will manage some of its activities. I have alluded to these changes in my earlier appearances before you and today I would like to spell them out in more detail.

I believe that the most valid, overriding goal for the Foundation to pursue now and for the foreseeable future continues to be maintenance of the health and vitality of this Nation's science and engineering enterprise. NSF's fiscal year 1984 budget request is most certainly a significant first step in the direction of insuring NSF's ability to realize this objective in the 1980's.

In considering the important opportunities that this request presents, it is both timely and appropriate that we ask ourselves two questions: How much does each of the activities supported by the Foundation contribute to the achievement of this overriding objective? And two, can NSF increase the likelihood of realizing the objective by improving the way in which it organizes and manages its programs?

Since becoming the Director of the Foundation, I have devoted much of my thinking to these questions and related issues. Increasingly, I have come to the view that NSF's present system of management may not be optimal for the future and may not permit the Foundation to realize fully the opportunities implicit in the budget request. In my judgment, the time is ripe for a reconsideration of NSF responsibilities and how they are managed.

The Foundation historically has had two modes of organizing and operating its activities. The first mode refers to activities organized in support of the scientific and engineering disciplines—what have been known informally as the research directorates—mathematical and physical sciences; astronomical, atmospheric, Earth and ocean sciences; biological, behavioral and social sciences; and engineering. These directorates are responsible for the management of most of NSF's resources.

Because these directorates are organized around disciplines, much as they exist in academic institutions, these programs have been quite stable, evolving and changing in response to scientific developments and shifts in priorities. The flow of proposals, peer reviews, advice from scientific panels and, occasionally, recommendations from more formal studies of disciplinary needs and priorities provide input into the decisionmaking process for program planning, budgeting, and the selection of research projects for support.

The goal of these programs has been straightforward and easily understood: to support the best research. Their emphasis has been on excellence and the production of new knowledge. Their performance is evaluated by examining the scientific quality of the work they have supported.

The second mode of organizing and operating the Foundation's activities is represented by a broad range of programs and activities organized separately from the research directorates. These have included educational programs, international science, intergovernmental science, industry university cooperative research, small business innovation research, programs for minorities and women, and undergraduate research initiatives.

As these examples suggest, these programs have not been organized around disciplines. They have been oriented toward particular institutions, groups, or issues. Their programmatic content, priorities, and budgets are often driven by changes in policy concerns of administrations and Congresses rather than by scientific developments.

The goals of these programs have been more complex than those of the activities in the research directorates. However, like the research directorates they have stressed excellence as indicated by peer review. They have also used additional criteria in setting priorities and selecting projects, since the work they support is expected to have an impact on institutions or groups beyond science itself.

Their peer reviewers and advisory panels are often heterogeneous. The resources they have dispensed have been small in comparison with those of the research programs. In the fiscal year 1984 budget request, most of these activities are displayed in the scientific, technological, and international affairs directorate.

After giving the matter much thought, I believe that this dual approach will not best serve the needs of U.S. science and engineering in the years immediately ahead.

There is a perception, external to the Foundation, that the quality of the work supported in the directed programs is not comparable to that supported in the research directorates. Because the directed programs are organized and managed independently of the research programs, additional concerns have been raised about duplication of effort, lack of impact, and service only to special interests.

Second, there is also a perception within the Foundation that one purpose of many of these programs; namely, to familiarize targeted groups with research directorate funding procedures and criteria, has not worked effectively.

In my judgment, the responsibilities of the research directorates have been defined too narrowly. For example, for some time there has been a tendency to deemphasize the educational aspects of research and to emphasize those aspects that lead to the procurement of new knowledge. But an important aspect of supporting research in universities is the education and training of future scientists and engineers. Indeed, if that were not so, there would be little justification for procuring research primarily from universities in the first place.

As my remarks before this committee last week indicated, in the future I expect to see education at the graduate and undergraduate levels become a prominent part of the responsibility of the research programs.

Another factor that no doubt has contributed to the narrowing of the responsibilities of the research directorates has been the very existence of special, targeted programs. Such programs inevitably, create the attitude among research program officers that these special issues are being taken care of elsewhere and therefore are outside their purview.

My intention is to integrate fully the responsibilities for the health of science and engineering into the mainstream of the research programs. I believe the research directorates must assume much broader responsibilities than they have in the past, along many new dimensions that have been until now the responsibility of the focused programs.

Similarly, the NSF staff for the directed programs must develop new partnerships with the research programs to assure that the responsibilities of the directed programs are met.

The assistant directors and program officers in the research programs must include considerations about the support of undergraduates, minorities, and women, and international science--to name a few examples—as they plan and budget for the support of their disciplines. The research directorates must have greater responsibility for evaluating and decisionmaking on research proposals handled previously by the directed programs.

For broad issues, such as the participation of women and minorities or the management of international science, it will be necessary to maintain agencywide coordination. This will be the responsibility of the STIA directorate. Its staff will provide a continuing assessment of progress toward Agency goals and insure that each of the research directorates receives the support necessary to meet its obligations. Precollege education will continue to receive separate management, with advice and cooperation from the research directorates.

I wish to assure you that the resources devoted to the directed programs will be maintained. I intend to establish a tracking system to insure this objective, both for internal management of the Foundation, and for accountability to the Congress. NSF will continue to issue announcements and continue to receive and support proposals for these programs. I am confident that these activities will flourish under this new approach.

The management style I have in mind is perhaps best illustrated with two examples. Consider the case of equipment and research at undergraduate institutions. Clearly these institutions are enormously important in producing the Nation's future scientists and engineers. In fact, some undergraduate institutions have records in this effort better than any of the major universities. It is essential, therefore, that the Foundation be sensitive to and supportive of such institutions.

Thus, I expect the research programs in the future to review and support proposals for research and research instrumentation submitted by small colleges. As at present, excellence will be the primary criterion; peer review will be used, and reviewers will be selected appropriately for the proposals.

Funding decisions will be consistent with the special circumstances surrounding research at undergraduate institutions. For example, the rate of progress and publication on research projects at these institutions is necessarily (and appropriately) slower than one expects from projects at a major research university. The research directorates will thus be responsible, in the disciplines they support, for the health of science and engineering at institutions that do not grant the Ph. D. as well as at the large institutions.

Another more complex example is international science. In this instance, the responsibilities of STIA will be more extensive, and absolutely essential, if NSF is to meet its obligations. Nevertheless, responsibility for the evaluation and formal recommendations regarding proposals involving international science will rest with the research directorates. The STIA directorate staff will evaluate the international aspects of these proposals and judge them accordingly. Thus, the final decision will be a joint one.

The STIA staff will maintain up-to-date awareness of international science and engineering by establishing and maintaining close partnerships with program officers in the research directorates and with their counterparts in other countries. The STIA staff also will be expected to maintain current awareness of international protocols, applicable laws, and broad U.S. Government policies and priorities and to keep me and the research program officers fully informed.

The research directorates will be responsible for considering international opportunities and cooperation as an essential element of the vitality of the disciplines they support. I believe this system will lead to greatly expanded international scientific cooperation which would benefit U.S. science and engineering.

I have discussed this shift in management responsibility with the National Science Board, with the Office of Science and Technology Policy, with the Office of Management and Budget, with three previous NSF Directors, with the Chairman of NSF's Committee on Equal Opportunities in Science and Technology, with the Women's Subcommittee of that committee, with the Steering Committee of the Director's Advisory Council, and with the Assistant Directors of the Foundation. The responses I have received range from concurrence to enthusiasm.

Consequently, I have asked the Assistant Directors of the Foundation to work out a detailed implementation plan which will: One, define responsibility between STIA and the research programs; two, track obligations so that the directed programs are supported at the levels desired or mandated; three, use advice from the several committees I just mentioned to insure a proper voice from the constituencies involved; and four, recommend personnel adjustments that may be required for the system to work optimally.

I wish to emphasize that I am proposing here the initial outline of a plan to be implemented in October, at the beginning of fiscal year 1984. Between now and then, many details are to be worked out. The Assistant Directors group I mentioned earlier has been meeting; it is discussing these proposals in the directorates and developing detailed responses. In addition, I plan to meet with Foundation staff in more informal sessions to discuss the ramifications of this plan.

I believe that these changes will enhance the integration of women and minorities and of international activities into the Foundation programs. They will further the goal of broadening the attention of the entire Foundation to the health of science and technology in the United States, including the educational and scientific communication aspects of NSF's research funding.

Mr. Chairman, you and the other members of this committee have always taken a great deal of interest in the Foundation and its programs. I am certain that you will be most interested in learning of its progress in making these changes in management responsibility. I shall be pleased to keep you informed as we proceed at the Foundation.

I believe that this plan will increase the Foundation's ability to capitalize on the opportunity offered by the fiscal year 1984 budget request to begin revitalizing this Nation's science and engineering enterprise. As I said at the beginning of my remarks, the assurance of the health and vitality of that enterprise is the Foundation's most valid and overriding goal.

[The prepared statement of Dr. Knapp follows:]

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and members of the committee, I am glad to be with you today for the last day of hearings before your Committee on authorization of the National Science Foundation. With me is Dr. Eugene H. Cota/Robles, Provost of Crown College and Professor of Biology, University of California at Santa Cruz.

The Foundation's fiscal year 1984 budget request proposes important changes in the way in which the NSF will manage some of its activities. I have alluded to these changes in my earlier appearances before you and today I would like to spell them out in more detail.

Mr. Chairman, I believe that the most valid, overriding goal for the Foundation to pursue now and for the foreseeable future continues to be maintenance of the health and vitality of this Nation's science and engineering enterprise. Our fiscal year 1984 budget request is most certainly a very significant first step in the direction of ensuring our ability to realize this objective in the 1980s.

In considering the important opportunities which this request presents, it is both timely and appropriate that we ask ourselves two questions: (1) how much does each of the activities which the Foundation supports contribute to the achievement of this overriding objective? and (2) can we increase the likelihood of realizing it by improving the way in which we organize and manage our programs? Since becoming the Director of the Foundation, I have devoted much of my thinking to these questions and related issues. Increasingly, I have come to the view that our present system of management may not be optimum for the future and may not permit us to realize fully the opportunities implicit in our budget request. In my judgment, the time is ripe for a reconsideration of our responsibilities and how we manage them.

The Foundation has traditionally had two modes of organizing and operating its activities. The first mode refers to those activities organized to support the scientific and engineering disciplines, what have been known informally as the "research directorates"—Mathematical and Physical Sciences; Astronomical, Atmospheric, Earth and Ocean Sciences; Biological, Behavioral and Social Sciences; and Engineering. These directorates are responsible for the management of most of NSF's resources.

Because these directorates are organized around disciplines, much as they exist in academic institutions, these programs have been quite stable, evolving and changing in response to scientific developments and shifts in priorities. The flow of proposals, peer reviews, advice from scientific panels and, occasionally, recommendations from more formal studies of disciplinary needs and priorities provide input into the decisionmaking process for program planning, budgeting, and the selection of research projects for support. The goal of these programs has been straightforward and easily understood: To support the best research. Their emphasis has been on excellence and the production of new knowledge. Their performance is evaluated by examining the scientific quality of the work they have supported.

The second mode of organizing and operating the Foundation's activities is represented by a broad range of programs and activities organized separately from the "research directorates." These have included educational programs, international science, intergovernmental science, industry/university cooperative research, small business innovation research, programs for minorities and women, and undergraduate research initiatives.

As these examples suggest, these programs have not generally been organized around disciplines. They have been oriented towards particular institutions, groups, or issues. Their programmatic content, priorities, and budgets are often driven by changes in policy concerns of Administrations and Congresses rather than by scientific developments.

The goals of these programs have been more complex than those of the activities in the "research directorates." However, like the "research directorates" they have stressed excellence as indicated by peer review. They have also used additional criteria in setting priorities and selecting projects, since the work they support is expected to have an impact on institutions or groups beyond science itself. Their peer reviewers and advisory panels are often heterogeneous. The resources they have dispensed have generally been small in comparison with those of the research programs. In the fiscal year 1984 Budget Request, most of these activities are displayed in the Scientific, Technological, and International Affairs Directorate.

After giving the matter much thought, I believe that this dual approach will not best serve the needs of U.S. science and engineering in the years immediately ahead.

There is the perception, external to the Foundation, that the quality of the work supported in the directed programs is not comparable to that supported in the "research directorates." Because the directed programs are organized and managed independently of the research programs, additional concerns have been raised about duplication of effort, lack of impact, and service only to special interests.

Second, there is also the perception within the Foundation that one purpose of many of these programs, namely, to familiarize targeted groups with standard research directorate funding procedures and criteria, has not worked effectively.

In my judgment, the responsibilities of the "research directorates" have been defined too narrowly. For example, for some time there has been a tendency to deemphasize the educational aspects of research and to emphasize those aspects that lead to the "procurement" of new knowledge. An exceedingly important aspect of supporting research in universities is the education and training of future scientists and engineers. Indeed, if that were not so, there would be little justification for "procuring" research primarily from universities in the first place. As my remarks before this Committee last week indicated, in the future I expect to see education at the graduate and undergraduate levels become a prominent part of the responsibility of the research programs.

Another factor that not doubt has contributed to the narrowing of the responsibilities of the "research directorates" has been the very existence of these special targeted programs in the first place. Such programs inevitably, even if subconsciously, create the attitude among research Program Officers that these special issues are being taken care of elsewhere and therefore are outside their purview.

My intention is to integrate more fully the responsibilities for the overall health of science and engineering into the mainstream of the research programs. I believe the "research directorates" must assume much broader responsibilities than they have in the past, along many new dimensions that have been until now the responsibility of the directed programs. Likewise, the NSF staff for the directed programs must develop new partnerships with the research programs to assure that the responsibilities of the directed programs are met.

The Program Officers and Assistant Directors in the research programs must include considerations about the support of undergraduates, minorities and women, and international science—to name a few examples—as they plan and budget for the support of their disciplines. The "research directorates" must have greater responsibility for evaluating and decisionmaking on research proposals that have been handled previously by the directed programs.

For broad issues, such as the participation of women and minorities or the management of international science, it will be necessary to maintain agency-wide coordination. This will be the responsibility of the STIA directorate. Its staff will provide a continuing assessment of progress toward agency goals and ensure that each of the "research directorates" receives the support necessary to meet its obligations. Precollege education will continue to require separate management, with advice and cooperation from the "research directorates."

I wish to assure you that the resources devoted to these pograms will be maintained. I intend to establish a tracking system to ensure that this is the case, both for purposes of internal management of the Foundation, and to be accountable to the Congress. We will continue to issue announcements and will continue to receive and support proposals for these programs. I am confident that these activities will flourish under this new approach.

The management style I have in mind is perhaps best illustrated with two examples. Consider the case of equipment and research at undergraduate institutions. Clearly these institutions are enormously important in producing the Nation's future scientists and engineers. In fact, some undergraduate institutions have a record in this regard that is better than any of our major universities. It is essential, therefore, that the Foundation be sensitive to and supportive of such institutions.

Thus, I expect the research programs, in the future, to review and support proposals for research and research instrumentation that come from small colleges. As is now the case, excellence will be the primary criterion; peer review will be used, and reviewers will be selected appropriately for the case involved. Funding decisions will be consistent with the special circumstances surrounding research at undergraduate institutions. For example, the rate of progress and publication on research projects at these institutions is necessarily (and appropriately) slower than one expects from projects at a major research university. The "research directorates" will thus be responsible, in the disciplines they support, for the health of science and engineering.

Another more complex example is international science. In this case, the responsibilities of STIA will be more extensive, and absolutely essential, if NSF is to meet it obligations. Nevertheless, responsibility for the evaluation and formal recommendations regarding proposals involving international science will rest with the "research directorates." The STIA directorate staff will evaluate the international aspects of these proposals. Thus, the final decision will be a joint one.

The STIA staff will maintain up-to-date awareness of international science and engineering by establishing and maintaining close partnerships with Program Officers in the "research directorates" as well as with their counterparts in other countries. STIA staff will also be expected to maintain current awareness of international protocols, applicable laws, and broad U.S. Government policies and priorities and to keep me and the research Program Officers fully informed.

The "research directorate" will have the responsibility of considering international opportunities and cooperation as an essential element of the vitality of the disciplines they support. I believe this system will, over time, lead to greatly expanded international scientific cooperation which would be to the benefit of U.S. science and engineering.

I have discussed this shift in management responsibility with the National Science Board, with the Office of Science and Technology Policy, with the Office of Management and Budget, with three previous NSF Directors, with the Chairman of our Committee on Equal Opportunities in Science and Technology, with the Women's Subcommittee of that Committee, with the Steering Committee of the Director's Advisory Council, and with the Assistant Directors of the Foundation. The responses I have received range from concurrence to enthusiasm.

As a result, I have asked the Assistant Directors of the Foundation to work out a detailed implementation plan which will:

1. Define responsibility between STIA coordinators and the research programs;
2. Track obligations so that the directed programs are supported at the levels desired or mandated;
3. Use advice from the several committees I just mentioned to ensure a proper voice from the constituencies involved; and
4. Recommend personnel adjustments that may be required for the system to work optimally.

I wish to emphasize that what I am proposing here is the initial outline of a plan to be implemented in October, at the beginning of the new fiscal year. Between now and then, there are many specific details to be worked out. The Assistant Director group I mentioned earlier has been meeting; they are discussing these proposals in their directorates and are developing detailed responses. In addition, I plan to meet with Foundation staff in more informal sessions to discuss the ramifications of this plan.

I believe that these changes will enhance the intergration of women and monorities and of international activities into the overall Foundation programs. It will further our goal of broadening the attention of the entire Foundation to the overall health of science and technology in the U.S., including the educational and scientific communication aspects of our research funding.

Mr. Chairman, I know that you and the other Members of this Committee have always taken a great deal of interest in the Foundation and its programs. I am certain that you will be most interested in learning of our progress in making these changes in management responsibility. I shall be pleased to keep you informed as we proceed. I believe that this plan will increase the Foundation's ability to capitalize on the opportunity which the fiscal year 1984 Budget Request offers us to begin revitalizing this Nation's science and engineering enterprise. As I said at the beginning of my remarks, the assurance of the health and vitality of that enterprise is our most valid overriding goal.

Mr. WALGREN. Thank you very much, Dr. Knapp.

Dr. Cota-Robles, do you have a statement?

Dr. COTA-ROBLES. No. I don't have a prepared statement. I will be happy to answer questions.

Mr. WALGREN. Thank you.

It is an interesting subject to pursue. As we indicated before, one concern is that when you integrate these programs in larger organizations, they will then get lost. As I understand it, you are recommending for the international programs some $5 million or thereabouts, maybe a little more funding to be transferred out of the STIA Directorate into the others; is that correct?

Dr. KNAPP. That is correct.

Mr. WALGREN. What happens to the 2- and 4-year college research instrumentation?

Dr. KNAPP. The 2- and 4-year college instrumentation program is not in the budget for fiscal year 1984. What is in the budget is an expanded program for research support at primarily undergraduate institutions. The program is targeted for a larger budget than the 2- and 4-year college instrumentation program had in the fiscal year 1983 budget.

Mr. WALGREN. What about the experimental program to stimulate competitive research?

Dr. **Knapp**. We propose to honor NSF's commitments to that program: $2.5 million in fiscal year 1984 for the continuation of grants at several universities.

Mr. **Walgren**. That program will end?

Dr. **Knapp**. It will end at the close of 1985.

Mr. **Walgren**. That program is the one in which there was a certain geographic distribution which we tried to allow to happen, as I understand it?

Dr. **Knapp**. That is correct.

Mr. **Walgren**. Apparently your testimony today is in pursuit of a January 12 memorandum outlining your proposal; is that correct?

Dr. **Knapp**. The January 12 memorandum, was an internal memorandum to members of the Executive Council of the Foundation. It asked the council to consider whether this plan would be possible.

Mr. **Walgren**. There is apparently language in that memorandum which would conflict at least somewhat with the thrust of your concept today of joint decisionmaking with the STIA people. Apparently it says in that memorandum that the research directorates would have—and I quote—"Sole responsibility for receiving, evaluating, and decisionmaking on all proposals."

Today we are talking about at least some level of joint decisionmaking. Can you develop the concept of the jointness of that decisionmaking? How would that work?

Dr. **Knapp**. The quotation deals with international programs. For some international programs within the Foundation, particularly those associated with bilateral agreements with other nations, there are aspects that concern the research to be done and also aspects that concern the foreign policy implications and the thrusts of the bilateral agreements.

I would expect the research directorates to be responsible for judging the scientific aspects of the program and the STIA directorate to be responsible for judging whether the proposals, satisfy the international agreements and goals of the U.S. Government.

The decision should be, a joint decision, not just on the research to be done, but on the research and on the international aspects. I believe that NSF can develop a management system that will allow such joint decisions to be made in a reasonable way.

The research aspects of some of NSF's international agreements have been criticized by various sources. The joint decision will alleviate such criticism and will not cause additional problems with the international aspects.

Mr. **Walgren**. The criticism has been of what, again? I am sorry.

Dr. **Knapp**. The quality of the science done in some of the programs.

Mr. **Walgren**. In your testimony, you indicate that that is a perception. I think that is the word you used.

Dr. **Knapp**. That is correct. That is the word I used. I personally——

Mr. **Walgren**. Do you feel that that is a correct perception?

Dr. **Knapp**. It is correct in some cases, incorrect in others. Some extremely good science is done in the international programs. But I think the range of investigators applying for grants within the international programs will be considerably wider if the research aspects are managed by the research directorates. These directorates have wider contact with any given discipline.

I think we will have a bigger pool of potential proposals under the new system of management.

Mr. **WALGREN**. You indicate there is a way to make that joint decision in a reasonable fashion. That is a tough decision to make, in a way. I don't know much about decisionmaking, really, particularly from a management standpoint. I just can only wonder would one part have a veto over the other part? Or how would you resolve differing views between these two partners in that decision?

Dr. **KNAPP**. The purpose of my working group of the NSF Assistant Directors is to determine whether we can develop a management system that will allow joint decisions to be made. I have no complete assurance that this is possible. If it is impossible, of course, we won't go forward this way. I believe that it is possible.

I also believe, however, that the correct people to develop such a joint decisionmaking mechanism are the people involved in the process themselves—not the Director of the Foundation saying it will be done this particular way.

Mr. **WALGREN**. In the budget, there are no line items within the research directorates for international programs. You indicate that you are going to have a tracking system for this effort internally. How would that work out?

Dr. **KNAPP**. These proposals are still separately directed to these programs when they are submitted to the Foundation; the tracking should be relatively straightforward. We now have a computer tracking system for applied research within the Foundation, and applied research is much more difficult to track, because a great deal of judgment is involved in deciding whether research is applied or basic. That tracking system seems to be working quite well. I think it was put in place at the request of your committee.

Mr. **WALGREN**. Let me at this point turn to my colleagues and recognize, first, Mr. Valentine, for any thoughts that he might want to raise.

Mr. **VALENTINE**. Mr. Chairman, I am involved with my colleague here in a learning process. We have been Members of Congress only a short period of time. Our questions will be to try to get some information. It may be very well known to everybody else here.

Doctor, in these documents you referred to international programs. Does that mean some type of scientific research that is conducted overseas or are we talking about grants that go to institutions or agencies in foreign countries, which would be in the nature of some type of foreign aid? Or what else do we mean by international programs?

Dr. **KNAPP**. What NSF means by international programs, in the context we are talking about this morning, are joint research programs, usually under an agreement established between, the United States and some other country. Scientists from the United States and scientists from a foreign country work jointly in cooperative pursuit of certain scientific research.

For example, under agreements with some South American countries United States scientists study the biology in, say, the Amazon Basin. The work gives American scientists access to sites outside the United States that are important to scientific research. It is not a foreign aid program. It can fund foreign scientists to come to the United States and work with United States scientists, but this is not a program of transferring money outside the United States for foreign governments to do research.

Mr. **Valentine**. Generally speaking—would a program of the kind you mentioned in South America be financed more or less entirely by this country or by the United States and the other country involved? Or is it kind of like the United Nations, we pick up most of the tab?

Dr. **Knapp**. There are both kinds of funding. In most cases, the research is jointly funded. This is particularly true with European partners in these enterprises.

In other cases with Third World countries, NSF may pay proportionately more of the cost.

Mr. Green would you like to comment?

Mr. **Green**. I am Mr. Richard Green, Assistant Director of the Scientific, Technological and International Affairs Directorate.

NSF currently participates in some 30 bilateral agreements for scientific cooperation. Typically, as Dr. Knapp indicated, we have joint funding arrangements which support cooperative science projects where the research is conducted in both the United States and in the foreign country. In certain limited instances, in the Third World countries, project costs are paid fully by NSF for the United States, but these projects are relatively small in scope and limited to the science in developing countries program.

Mr. **Valentine**. Thank you very much.

Mr. **Walgren**. Thank you, Mr. Valentine.

Mr. **Reid**. I have no questions.

Mr. **Walgren**. Thank you, Mr. Reid.

I would like to say we are all learning in this process. The truth of the matter is that I only became focused on this a short time ago. So, believe me, all the information that we get is new to me. No one should think that anybody has been over that ground before because chances are we have not.

Dr. Knapp, I would like to ask again about the social and the behavioral sciences. I cannot help but be struck by the fact that there is a tremendous gap in our knowledge in this area and in the attention, or the lack of attention that it has received over the years from the National Science Foundation, compared to other sciences. I know there are some reasons for that, but we did go through a rather arbitrary and politically driven reduction in the behavioral and social sciences in 1980.

The new administration, the testimony showed, did not review their proposals with anyone in the National Science Foundation until the proposals were presented 24 hours before being sent to the Hill by the Office of Management and Budget. In those proposals were an extremely deep and selective cut in social and behavioral sciences. You didn't have to fall off the turnip truck yesterday to know that this administration did not approve, on a political basis, of social engineering and Government involvement in areas that are admittedly controversial.

I cannot help but note that Stanford University conducts a program of science reeducation for its graduates and particularly many, many management people. In that program, they have found that although the social sciences are the most controversial at the outset, they are the most valued by the Stanford graduates in the retrospective evaluation of their scientific exposure.

I am not talking about students at this point, but I am talking about the alumni that come back for what is known as Alumni College, or whatever it is called.

I just walked down the Mall and I see, on the one hand, the Einstein Memorial. Fifty yards across the way is a memorial to our inability to structure human relationships in a way that we don't kill each other. Every evidence also shows that incredibly interwoven with any economic problems that we have are how the human beings are interacting with the system.

There are real grounds for the statement made by some, that the greatest potential to increased economic productivity involves the human interaction with the economic system in whatever stage it is.

Given all the potential in that area, and given the nonscientific base of the reduction in that area, I cannot help but note that we are still much behind in social and behavioral sciences when you start from a base year of 1980 and measure the National Science Foundation's effort.

Although there is an increase—and I applaud that increase and want to encourage you in that—the truth of it is that the increases in the other areas are in greater amounts; and, therefore, the relative effort is still declining under your recommendations.

The congressional committees have not supported that decline. The congressional committees have asked in each case that the social and behavioral sciences be brought back to the level of funding that they experienced before this truly arbitrary reduction. We are still some 22 percent below the level of 1980 in our 1984 budget, whereas every other part of the National Science Foundation is substantially above the 1980 level.

Do you really want to preside over an administration of the National Science Foundation that is not increasing its attention to behavioral and social sciences?

Dr. **Knapp**. I have been the Director of the National Science Foundation only a short time. I am not an expert in any of the social or behavioral sciences. I feel myself incompetent to make value judgments among various social and behavioral sciences or to judge their value with respect to other sciences. I have discussed the social and behavioral sciences with several social and behavioral scientists who have come to visit me. In many cases, these sciences are extremely valuable. They should be supported and supported well, within the Foundation.

I won't have to make that sort of decision until I come to the fiscal year 1985 budget, the first one I will really affect. However, let me say that we tried in the Foundation, with the resources at hand, to give the social and behavioral sciences an increase in the fiscal year 1984 budget commensurate with the other sciences and the funds at NSF's disposal.

Perhaps Dr. Cota-Robles would like to comment. He represents the National Science Board here. He also helps to set budget priorities within the Foundation.

Dr. Cota-Robles. You are aware that the Board has stated it is important that the social and behavioral sciences be included within the scientific enterprise. In June 1981, the Board made a clear statement about its concern for continuing to support those sciences and for including them within the National Science Foundation.

The Board, of course, has emphasized certain quantitative areas. The data bases absolutely should be maintained, and the Board has done so. We are trying to bring the other areas back.

I might remind you that some other areas in the National Science Foundation have been cut severely. For example, mathematics was cut in the mid-1970's. The Board is trying to bring that area back. When there have been cuts, The Board has tried to return the funding to the highest level appropriate within the total planning.

I believe the Board is committed to continued support of the social sciences. I serve on the Budget Committee. We have a social scientist sitting as chairman of the Budget Committee. He does present these needs completely as well.

Mr. Walgren. I certainly appreciate that. I do want to emphasize that other committees that have looked at the National Science Foundation's budget from a public representative standpoint have given the same direction, really; and with one thing and another, given the contradictions in the appropriating and the placement of dollars process in the Congress.

We have not mandated those 1980 dollars; but the committees themselves had directed that the behavioral and social sciences effort be returned at least to the fiscal year 1980 level. It really was simply the slip between the cogs of the wheel and in some part the discretion that the Director of the National Science Foundation has under the process, or under the last appropriation, as I understand it, that has resulted in that not being the case.

You indicate that you have tried to bring this back within appropriate planning—in Dr. Cota-Robles' words. In Dr. Knapp's words, "we gave them an increase that was commensurate to the others in this system."

Is there any way you can describe to us the competition that led to the deciding of what is the "commensurate increase" and what is the—well, within appropriate planning? It is a separate effort. I do realize at some point we have to sit down and allocate dollars. But one notes that astronomical, atmospheric, Earth, and ocean sciences come up 54 percent above the previous level and social and behavioral sciences are 22 percent below the previous level—and we are not talking about big dollars in the overall sense, we are talking about an effort that is about $16 million out of a $1 billion-plus budget. How do you weigh that commensurate increase? What is behind the word "commensurate"?

Dr. Knapp. The situation in almost all of the physical sciences has been a disastrous lack of instrumentation. NSF's first priority in the budget for fiscal year 1984 was to address the problems of instrumentation. The social sciences do not require instrumentation of the general type needed by the physical sciences.

So we tried first to address the instrumentation problem. And we tried to address a serious problem in mathematics that had developed over 10 years in the funding of graduate students and postdoctoral fellows. Mathematics also survived a serious cut in the early 1970's resulting primarily from the reduction in funding for mathematics from the Department of Defense, not from the Foundation.

In that context, I believe the social sciences received funding increases that are roughly the same as those received by the physical sciences.

Mr. **Walgren**. Well, I understand that commensurate might mean roughly the same; and yet, it strikes me that the committees of the Congress were looking for a restoration rather than the same treatment at that point.

Let me ask this question: It is my understanding that there is a certain amount of undistributed fiscal year 1983 moneys, $4.5 million. Is that available for living up to the directions of the Congress and those committees with respect to social and behavioral sciences?

Dr. **Knapp**. The $4.5 million in undistributed funds were in the budget for the ocean-drilling program and were to be allocated between the ocean-drilling program and other programs of the Foundation, depending upon the outcome of the ad hoc advisory group on crustal studies.

At the present time we are studying the procedures that we will follow in the crustal studies program. We will have a recommendation within the Foundation for the allocation of those funds in about a month.

Mr. **Walgren**. We would be very interested in that recommendation for the allocation of moneys. If I remember the drilling program testimony, we are looking at saving some money from original expectations in that program.

Dr. **Knapp**. That is correct.

Mr. **Walgren**. That would mean that there may be some funds that had been intended for that program that should be redirected. I would trust that the Congress would play some role in redirecting those moneys.

Dr. **Knapp**. The Congress would be asked to approve whatever allocation NSF makes of those funds.

Mr. **Walgren**. Let me ask my colleagues for any further thoughts?

Mr. Dymally.

Mr. **Dymally**. Thank you, Mr. Chairman.

Dr. Knapp, I observe that you said you weren't an expert in social science. I am not an expert in science either. I observe with some concern that 10 of the 13 advisers of the President are from the hard sciences. Is it because you don't look at the social sciences as significant in the NSF objectives?

Dr. **Knapp**. You are talking about membership on the National Science Board?

Mr. **Dymally**. Yes.

Dr. **Knapp**. The statute which established the National Science Board——

Mr. **Dymally**. I think it was the President's advisers I referred to.

Dr. **Knapp**. Oh, the President's Advisory Committee.

Mr. DYMALLY. Yes. You don't talk to the President every morning?

Dr. KNAPP. The President's Advisory Committee advises Dr. George Keyworth, the President's science adviser. I have nothing to do with the committee or how it is chosen or what its membership is.

Since the committee advises Dr. Keyworth, its members are people whom he feels he can ask for advice. The members may not be broadly representative of science.

Mr. DYMALLY. Of course, Dr. Keyworth influences the budgetary process for NSF because in the final analysis he works with OMB, I am sure?

Dr. KNAPP. Yes.

Mr. DYMALLY. So in the absence of any input from the social sciences we find a diminution of emphasis on social sciences. I raise that to lead to another question.

Even though your name gives the impression you are embarked on hard sciences, you also have human factors involved in NSF's mission. It is a question of women, minorities, and the handicapped. What bothers me a little bit is in your new management plan I am not so sure that there will be sufficient emphasis on the human factor.

Dr. KNAPP. I believe there will be more emphasis on human factors in the new way of managing the Foundation. Program managers in the scientific disciplines disbursing the greatest amount of NSF funds should be responsible for considering human factors in the funding of science particularly in funding the graduate education of most of the scientists of the future.

The amounts of money to be spent on these programs are not to be diminished in any way by managing in a different manner. In fact, no organizational change is required for the new management system to work. It is a matter of emphasis within the research directorates. I am asking that this emphasis be not only in the set-aside, or mandated, programs, but also in the general programs of the Foundation's directorates.

Mr. DYMALLY. You said research. I hope you weren't strengthening my bias by suggesting that these people are really concerned with dispensing money for research not for bringing some of the people into the system. I guess you may have those human factors——

Dr. KNAPP. NSF brings people into the research system by making it possible for them to do research of high quality, so that the next time they apply they will be more likely to be successful in the pursuit of a research career.

Mr. DYMALLY. You see——

Dr. KNAPP. There is no intention to diminish the funds NSF uses to bring new people, minority people and women into the research system. We hope that by managing in a different way, we can make it easier for those people once in the system to stay in the system.

Mr. DYMALLY. Dr. Cota-Robles.

Mr. COTA-ROBLES. I just wanted to say the responsibility is not only to support research, but also to develop personnel and develop the available talent. The Foundation has not pulled back on its commitment to try to further develop the American talent pool and the resources to do science.

Mr. **Dymally**. What I am hearing from Dr. Knapp and from you, Dr. Cota-Robles, really are assurances there will be some emphasis on that part of the mission also?

Dr. **Knapp**. Absolutely; that is correct.

Mr. **Dymally**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Dymally.

Other comments?

Let me recognize Dr. Maxwell for a question at this point.

Dr. **Maxwell**. Thank you, Mr. Chairman.

I would like to follow up on a point made by Dr. Knapp earlier on the international activities. You stated that you felt by making the change as you have outlined in your memo and in your testimony that you expected this would encourage a larger pool of researchers to be made available for participation in international activities. That is laudable. In fact, I would hope we could encourage more researchers to participate and be involved in international aspects.

The perception in NSF, as we noted earlier also, is probably just as important as reality. The perception of anyone who looks at the budget and is familiar with international activities as opposed to the domestic activities would note that there has been a 50 percent decline in support of international activities commensurate with a substantial increase in the research activities overall of the entire Foundation.

Why would you expect then that given that perception you would have a larger pool of researchers? Wouldn't, in fact, we see a situation where given the perception of less emphasis on international programs, less moneys made available, that there would, in fact, be less inclination by the researchers in general to propose to NSF international activities?

Let me follow up on that. You also stated that you felt the decision would be made jointly by the research program managers who would make value judgments based on scientific criteria of research proposals on activities that by and large, as you also noted, are designed to take into account other priorities. In fact, scientific criteria are probably the least of the priorities that are considered for these particlar programs, and that is why in the past they have been separated from the research proposals. Yet, you are in a situation where you place the money in the hands of people who will turn the system around entirely and will be asked to make criteria judgments that don't take into account, at least as one looks at it now, the policy and the foreign assessment needs that we have.

I guess that leads to my bottom line. Why not simply have those directors more involved in making recommendations, and why not place the emphasis in international activities in a way that the perceptions as well as the realities such that we are trying to increase focus on international activities rather than the perception that seems to be coming forward that you are deemphasizing that activity?

Dr. **Knapp**. Let me start with the first part of your question about the budget for international activities. The budget for such activities is not reduced. It provides $5 million to STIA, and more than $5 million to be distributed in the research directorates with the requirement that those funds be used for international activities. So the budget for international activities is the same or slightly enhanced from fiscal year 1983.

Mr. **Maxwell**. It is only if one looks at that activity that you see yes, there is money supposedly available in the other directorates; yet nowhere in the rest of the budget does it indicate there are any international money in any of the directorates.

It only states it in one line and shows a decrease in the STIA activities.

Dr. **Knapp**. I thought we had in the budget the total amount for international activities. It includes the amount for STIA plus the amount allocated to the directorates. If we do not, I will provide something for the record to show it.

Mr. **Maxwell**. It shows the total amount. It does not show in each of the directorates there is an international line provided within each directorate. It is only within the STIA budget line that shows elsewhere in the activities we will do 4.9 million dollars worth of activities, or $5.9.

Dr. **Knapp**. We intend to show within the budget the amounts to be spent by the Foundation. The sum includes the amounts for the directorates plus the amounts for STIA. We will work with you to develop a display mechanism within the budget that allows the amounts to be seen clearly.

As for the second part of your question, I believe that the division of responsibilities between the directorates and the international management aspects located in STIA will make the program managers much more aware of international opportunities. In the managers' discussions with the scientific community they serve, these opportunities will become more widely known throughout entire scientific disciplines; and I believe that knowledge will lead to enhanced participation in the international activities of an entire discipline. I can say only that that is my belief. I have no proof that it would certainly be the case.

Mr. **Maxwell**. As I said at the outset, I think what is perhaps more important than anything else is the perception of what is being attempted as well as the reality. I think we will probably want to explore how we can enhance perception that we are trying to focus more directly on international activities. As I know, it is hard to try to involve the program manager activities within the research directorates more directly with international programs. I would suggest there are probably some questions here that rise when you appear to be reducing a budget by some 50 percent and decreasing the emphasis when, in fact, you are trying to do the opposite.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Maxwell.

The Chair recognizes counsel for the minority.

Ms. **Bach**. I would like to change the line of questioning to some of the current vacancies you have in the top level of NSF, one being the Deputy Director.

As I understand, there are other vacancies. This has caused concern for members on this subcommittee as well as the full committee since we understand there is a clear perception the White

House is anxious to move on this. Could you indicate to us what kind of time schedule you are on for filling these vacancies?

Dr. KNAPP. Yes; I can. The Board and Director jointly nominate candidates for these positions. The White House then makes the final nominations. For the position of Deputy Director, we have narrowed a list of some 90 nominees from outside organizations to a more manageable size. The list will be voted upon next Thursday, I hope, by the National Science Board. It then will be delivered to the White House.

The nominees for Assistant Director positions should be chosen at the April Board meeting.

Ms. BACH. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you.

We will hold the record open for written questions that members might like to submit. We want to thank you very much for your testimony, Dr. Knapp. It has been good having you at these several hearings. We look forward to working with you in the follow-on.

Dr. KNAPP. Thank you.

Mr. WALGREN. Thank you, Dr. Cota-Robles.

The next panel is focused on the biological and behavioral sciences. Dr. Thomas Juster, University of Michigan; Dr. Herschel Leibowitz from Penn State University; and Mr. Joe Wyatt, Chancellor of Vanderbilt University. Would those gentlemen please come forward.

STATEMENTS OF DR. THOMAS JUSTER, UNIVERSITY OF MICHIGAN; HERSCHEL LEIBOWITZ, PENN STATE UNIVERSITY; AND JOE WYATT, CHANCELLOR, VANDERBILT UNIVERSITY

Mr. WALGREN. We appreciate your coming. Please proceed to summarize in whatever way you feel would be most effective in making the points you feel deserve to be emphasized.

Dr. JUSTER. Thank you, Mr. Chairman.

First, I would like to express my appreciation for being able to testify before this committee. I would especially like to register my thanks, and that of my colleagues, for the strong support this subcommittee has given to the social and behavioral sciences over the last several years. That support has been crucial, as I am sure you know, in maintaining a semblance of strength in those programs and prevented them from eroding more substantially than would have been the case.

I would like to summarize the first part of my comments. Let me begin with a general framework. I would like to use the general perceptions that are reflected in the testimony that Dr. Knapp provided several weeks back before the HUD-Independent Agencies Committee.

In that statement, Dr. Knapp suggested that the substantial increase requested for the NSF in the 1984 budget reflected the importance of basic research in laying the groundwork for sustained economic recovery and recognition of the need to revitalize the research base in the Nation's universities and colleges to ensure ability to produce world-class scientists and engineers.

Dr. Knapp proceeded to quote from Dr. George Keyworth as remarking that "Somehow we have arrived at the indefensible position of creating the poorest climate for research in the place, the United States, that ought to have the best."

I fully endorse those comments of Drs. Knapp and Keyworth. But I respectfully submit that the fiscal year 1984 budget request does not adequately reflect the application of those priority principles.

I would like to be sure the committee understands my position. I support with a good deal of enthusiasm the large increases in mathematics, physics, ocean, engineering and biological sciences. These programs represent needed investments in ensuring the Nation's technological well-being.

In an era where our national well-being is increasingly dependent on being at the cutting edge of technology, we can ill afford to continue the previous pattern of halfhearted support leading to technological second-class citizenship.

But these national goals will not be reached by emphasizing the importance of research in the physical and natural sciences alone. Much of our productivity problem has behavioral rather than technological roots, as the Japanese have taught us so well. Much of our capital stock consists of human skills and not machinery and equipment: optimizing the use of those skills in a rapidly changing technological world, and learning how to do a better job of shaping those skills in the first place, are behavioral and not technological problems.

And poverty, family instability, crime, inflation, and aging have enormous impacts on individual and national well-being, and none of them represent problems that can be fixed with an improved understanding of the physical and natural world.

In short, we depend, as a society, at least as much on advances in the social and behavioral sciences as on those in the physical and natural sciences. In my judgment, the fiscal year 1984 budget request meets neither scientific opportunities nor important national goals in this area.

I would like to turn now to illustrate what the social and behavioral sciences do with a concrete example of an active research project which I think has had enormous scientific benefits and changed the way we think. This is by way of an illustration of the way in which the social sciences function.

During the sixties and seventies we had repeated observations on the size and characteristics of the poor and welfare-dependent population in the United States, suggested that we were becoming a nation with a permanent underclass: the fraction of household below the poverty line dropped steadily throughout the sixties, but the decline came to a halt in the early seventies and continued at about the same level throughout the rest of the decade.

The poor could generally be characterized as disproportionately less well educated, disproportionately black, disproportionately old, and disproportionately female. This series of observations, derived from cross-sectional surveys conducted by the U.S. Census Bureau, gave rise to the notion that a culture of poverty and dependency was creating a permanent underclass of something like 10 percent of U.S. households.

Starting in the late sixties, the then Office of Economic Opportunity started a long-term study of poverty and dependency. The study, which consisted of careful measurements of income and individual characteristics thought to be associated with income change, continued throughout the seventies and the eighties.

The design of the data base was unique, in that the same individuals have been followed since the late sixties, thus making it a longitudinal panel rather than a series of repeated cross-sections of individuals.

What has this study shown about the nature of behavioral theories of poverty and dependency? First, virtually every stereotype about the poor and dependent population of the United States has been shown to be wrong. Second, this study has demonstrated that achieving a solid understanding of behavioral processes, and thus a solid foundation for the advancement of scientific understanding, will often require data bases designed to follow individuals or other units longitudinally through time.

One of my colleagues expressed that thought in the title of a recent paper—"The Dynamics of Poverty and Dependency: Or Why Everything You've Ever Learned From Cross-sections Is Likely To Be Wrong."

I can summarize the results of the poverty study as follows:

First, it is indeed true that the fraction of U.S. households living in poverty, or recipients of welfare, remained roughly constant throughout the decade of the seventies. The poverty population has been roughly 10 percent of U.S. households during this period, while the welfare receiving population has been roughly 8 percent.

Second, it is also true that the poor and dependent are always disproportionately less well educated, black, elderly, and female.

Third, it is demonstrably not true that the poor and dependent are the same people over time, as the cross-section studies seemed to suggest.

The facts are while roughly 10 percent are below the poverty threshold each year, over the period of a decade just about a fourth of the U.S. population is below the poverty threshould during at least 1 year out of the 10, while less than 1 percent—to be precise, seven-tenths of 1 percent—is below the poverty threshold during every one of the 10 years.

On dependency, while roughly 8 percent of the population received welfare each year during the decade, fully 25 percent of the population were on the welfare system for at least 1 year of the decade, and less than 1 percent—again, precisely seven-tenths of 1 percent—were dependent on welfare all the time.

The upshot is that any theory of poverty and dependency has to account for the fact that there is enormous turnover in the poor and dependent population, rather than constancy. It may be true that the poor are always with us, but they are largely different people from one year to the next, a finding with obvious implications both for models of behavior and for the formulation of public policy.

I would like to turn now to a brief discussion of research activities that seem to me of the highest priority, and which I judge to be impossible to support within the budget constraints in the fiscal year 1984 recommendation for the social and behavioral science areas.

First, let me note that it is a welcome change to see a budget request which contains significant increases for research programs in these areas. The budget will permit continuation of a number of highly important programs, including maintenance of several high priority data bases.

These include the general social survey, the panel study of income dynamics, which is the data base I described just above, and the national election studies. In addition, a set of essential activities of different sorts, consistent with the framework that I have described in my written statement, are also able to be supported within the fiscal year 1984 budget request.

But there are a number of areas in which additional resources would permit research that is both highly important in scientific terms and compatible with the administration's objective of supporting research with the potential for furthering important economic and other national goals.

The question to be addressed is; given the budget request, what can be accommodated in terms of research, and what will be lost?

I would note three general types of things that we would lose. There are general effects, there are some measurement instrument effects, and there is a collection of effects which are outside of measurement instrument issues.

On the general effects, I would like to suggest that the science program in the NSF needs to have the character of encouraging young people to pursue scientific careers. If you ask what is the consequence on the encouragment of young scientists to become social and behavioral scientists of a 40-percent decline in real terms between 1980 and 1984, the answer is: it must be very discouraging.

No bright young person is going to look at those numbers and decide that social and behavioral sciences is a good place to pursue a career. Off the top, you start out with a general discouragement of young people going into an area where they know that support has been given less priority.

Concretely, in the NSF programs, that reduction has had the effect across most of the programs of reduced support for young investigators because they are more high risk; reduced support for high-risk projects; reduced support for graduate students, for those people who get grants, the grants are smaller, and contain little or no support for graduate students. These are, of course, the seed corn from which future scientists will come.

Finally, for people who are more mature, who have prospects of getting grants and can apply for them and do, in general, they are discouraged from ambitious projects because they know full well that an ambitious and costly project has little prospect of being funded. They simply won't create things at the cutting edge.

Those are the generalized effects. They are quite important. I think they are well summarized in the quote I gave to you earlier from Dr. Keyworth where he said we have managed to create the worst climate in the place that ought to have the best.

Let me turn to some of the measurement project issues. There is a good deal of emphasis in Dr. Knapp's testimony and the testimony of others that one of the things we need to do is produce a much more effective level of instrumentation. For social and behavioral scientists, instrumentation has a number of forms. One is these longitudinal and other kinds of data bases. These are the measuring instruments used by the social scientists. I have spoken to those already.

Another one which surprises a lot of people is that social scientists are very intensive users of various kinds of instruments, in particular computing. There seems to be a perception that by and large all a social scientist needs to function is a piece of chalk and a blackboard.

At the University of Michigan I took a look at the numbers generated by our computing center—probably the largest university-based computing center in the United States save for two which have big supercomputers. At Michigan, 35 percent of the usage of computers is by social and behavioral scientists. About 40 to 50 percent of our faculty are social and behavioral scientists. Those ratios are not very different.

Thus we are just about as computer-intensive as anybody else, which was a surprise to me and apparently is a shock to most people who view social science as not requiring the kinds of instrumentation and the kinds of needs that physical and natural sciences have. That used to be true 50 years ago.

There has been a revolution in social science methods—they are data intensive, computer intensive, and instrument intensive. The needs there are as great as in the natural and physical sciences.

On the measurement projects let me make two general points. First, one cannot think of a measurement project in isolation. In order for it to be effective, there have to be research activities that precede conceptualization, theorizing, and research activities that go after testing, refinement, elaboration. Those are expensive. They are not perhaps as expensive as the generation of the data bases. But you cannot think that a program can generate data and that is the end of it. There has to be a portfolio or package associated with these projects.

Second, many people—and I am certainly among them—are beginning to come to the conclusion that for most purposes, the most effective kinds of measurements in scientific terms have got to be longitudinal. The reason is that we are often concerned with trying to follow a process through time. You cannot follow a process with repeated cross-sections and you will be misled, as the example I cited to you earlier.

You will be misled more often than not by what you find looking at differences in people at the same point in time. You have to follow people, organizations and units over time. That is expensive because every time you do it, you have to pay for it. On the other hand, the scientific potential grows exponentially with the length of the period you follow. You can take account of more process and more lags. It is a characteristic of research that I think is crucially important.

In specific programs, the 1984 budget request will accommodate at least three major data bases and a number of other smaller ones. The ones it will accommodate are the National Elections Study, the Panel Study of Income Dynamics, and the General Social Survey

It cannot accommodate a large number of others. In my testimony, I have detailed four areas in which I think a major investment in longitudinal data bases would produce enormous scientific and public policy payoffs. I will mention them. They are discussed at length in the testimony. I would be happy to discuss them in the question period.

The areas I focus on are measures of personal savings behavior which are totally absent; measures of organizational behavior and a data base which is a combination of economic and organizational variables which is lacking and crucially important for understanding productivity; measurements of time use, important for understanding the generation of well-being in the market and nonmarket sector; and measures of changes over time in the ties between families—which are rapidly changing.

We don't know anything about the nature of those family relationships and how they are changing over time and what they are doing to the environment in which children are being raised.

Those are, I would think, four key areas where measurement projects are ripe and could be exploited and cannot be done within the budget.

In other areas—let me skim them briefly—there is a set of activities going on which has to do with the theory of markets. Economists have generated a theory of markets which is deductive, that is, we make inferences on the basis of assumptions about what kind of objectives people are trying to accomplish.

Recent work has tried to simulate the behavior of markets in an experimental setting. It turns out you can do this in a way which reproduces the characteristics of markets provided you incur the costs of paying people and imposing real costs on them so you can make realistic markets come out of simulated behavior. That is provocative because you can then begin to examine some of the innards of markets in an experimental setting which you cannot do in a natural setting.

The whole notion is attractive, exciting and provocative. It can also be extended to markets in which you don't use prices. For example, bureaucratic decisions are a kind of market. You can simulate those. We would learn a good deal about how other parts of society function. Political decisions can be thought of as a kind of market without prices because you can't measure the output.

That methodology is applicable to those kinds of markets as well as money kinds of markets and is quite exciting. It can't continue because it is very expensive. You have to pay people and you have to do this repeatedly. That program is going down the tubes, as best I can tell. It is at a low level and should be at a high level.

We have major areas in statistical methods which are crucially needed and can't be supported. I mentioned longitudinal data bases as a measurement device which is increasingly important. The methods for handling those are somewhat different than the conventional methods for handling other kinds of data.

The data themselves have a longitudinal characteristic and the error structures are somewhat different. There needs to be a major investment in developing methods of analysis for longitudinal data. There have been proposals to do that. They can't be funded.

Similarly, we all know macroeconmoic modeling is in disfavor these days. One notion about why such models have problems is that they make an assumption that there is underlying stability in the structure of the system they are modeling.

Recent theoretical developments suggest that the structure is unstable. You can get at that problem with the development of estimation techniques. There have been programs proposed to do that. Again, they cannot be supported.

Let me note a few applications. We are all aware of the fact that the courts are clogged. We have civil suits dealing with things like divorce and accidents and compensation. They impose enormous burdens and costs. There is evidence to suggest that mediation is a more cost-effective and beneficial way of handling those cases than jury trials. One could design experiments in which you either force people into mediation, allow them free choice, or preclude them from mediation. You could measure the costs and outcomes. It may turn out that is extremely profitable to force mediation. One could adopt a policy on the basis of what those experiments show. They can't be done. They are very expensive.

We have a long concern with crime, criminals, and the effects of deterrence. You can't really get at that problem, in the view of people who study it carefully, without the combination of longitudinal data which includes information relating to individuals and traces them through time, and information relating to the organizational complex in which criminals get processed as they become caught and as they get punishments.

So the data base which combines characteristics of people who go through the system and the characteristics of systems followed longitudinally, might provide us with insights into what might be effective deterrence. We do not now have that knowledge and cannot now get it with present resources.

I think the committee will realize this list of things I have specified is a very idiosyncratic agenda. They are things that occurred to me as things that can be done. If you had somebody else testifying, you would have five other things. There would be overlap, but not all that much.

If you ask how much would it cost to put that kind of program in place and what would you get from it, I can give you some rough-cut numbers about what the benefits might be and what it would cost. Then I can extrapolate that in terms of saying what the whole program might cost. The benefits I can only do in terms of two kinds of things. A lot of these things cannot be easily quantified.

I would suggest to you that on savings behavior—the need to understand it and therefore devise policies which might be able to influence it—and the need to develop a longitudinal view of productivity and organizational effectiveness, one would expect the payoff to be some modification of the rate of growth of productivity.

That is the ultimate payoff from better understanding there. It doesn't take much gain to produce an enormous benefit. If either of those kinds of studies could produce a one-tenth of 1 percent gain, which is not a major expectation, the outcome is that you are $3 billion better off annually. Three billion dollars is a pretty big payoff no matter how much those programs cost. They are cheap in comparison.

If you could actually devise a strategy for increasing the deterrent effect of various kinds of policies vis-a-vis crime, you would realize enormous benefits. The cost of crime runs to the tens, if not hundreds, of billions. Hence, even a small dent, a small percentage reduction in crime as a consequence of devising a better and more effective deterrent based on a solid understanding of the processes involved, has to pay very large dividends.

On other things I find it difficult to say anything sensible about benefits. On the cost side, all I can tell you is I have looked at what I suggested and put price tags on them. In general, I am talking about programs which have to have continuity. Anything worth doing in those areas has to be continued for a long period of time. I am talking about annual costs for a set of new programs which might or might not be the ones funded if the NSF had more resourses in these areas. There is a peer review process and no one can tell the NSF what they should fund.

For the list I gave you savings, organizations, nonmarket activities, families, theory, methods and applications my guess about the annual cost of doing them properly is $12.5 million. These programs might cover something like 40 percent of the social and behavioral programs of the National Science Foundation. If I figured that the other 60 percent has the same potential, my $12.5 million turns into $30 million. That is not an unreasonable number.

If you were to ask me concretely would I recommend an increase in the social and behavioral programs for fiscal year 1984 of $30 million, in good conscience I would probably have to say no, I would not recommend that. You can't make things turn around that quickly and do it wisely and effectively and in cost-conscious terms.

What I would like this committee to do is recognize there are major untapped potentials in the social and behavioral sciences that cannot be accommodated within the budget. They do have an order of magnitude of something like $30 million, which is close to double the original recommendation. A sensible stance is to say let's do it in steps.

Let's put in $10 to $15 million this year, which would not be inappropriate. Have a recommendation in there which says in the following year that an additional $15 or $20 million should be put in to bring those programs to the point, not where they are at parity with other programs, but where they realize a better share of their scientific potential.

I think the basic argument has to be: "what is it that you cannot get if you leave the programs at the levels they are now," not "are the ratios and changes equal across all the programs".

My sense is there is a great deal you cannot get with the programs at these levels. I have given you a number for it. I have given you a trajectory strategy. That is what I would urge the committee to do. That is about as close as I can come to a concrete recommendation.

[The prepared statement of Dr. Juster follows:]

STATEMENT OF DR. F. THOMAS JUSTER

Director, Institute for Social Research
Professor of Economics, The University of Michigan

on the

SOCIAL AND BEHAVIORAL SCIENCE PROGRAMS

OF THE NATIONAL SCIENCE FOUNDATION

PREPARED FOR THE

HOUSE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

The Honorable Doug Walgren, Chairman

March 10, 1983

INTRODUCTION

Chairman Walgren and Members of the Subcommittee: My name is F. Thomas Juster, and I am Director of the Institute for Social Research and Professor of Economics at The University of Michigan. I am testifying on behalf of my own institution and university, and on behalf of the Consortium of Social Science Associations, which represents some 150,000 social and behavioral scientists in the United States.

I appreciate the opportunity to appear before this Subcommittee and to present testimony in regard to the National Science Foundation's budget request for FY 1984: this Subcommittee has in the past been a strong and vigorous supporter of the NSF social and behavioral science programs, and my colleagues and I are greatly appreciative of that support.

Let me start by noting the principal characteristics of the NSF budget request for FY 1984. The data appear in Table 1, and can be summarized briefly as follows:

1. The Directorates for Mathematical and Physical Sciences (MPS), and Astronomical, Atmospheric, Earth, and Ocean Sciences (AAEO) are increased by slightly over 20 percent from last year, enough to bring them significantly above their FY 1980 level in terms of real dollars;
2. The biological science parts of the Directorate for Biological, Behavioral, and Social Sciences (BBS) are increased by a bit under 20 percent, which brings them slightly above their FY 1980 level in terms of real dollars;
3. The social and behavioral science programs in BBS are increased by a bit over 10 percent, which puts them 22 percent below their nominal 1980 level, roughly 40 percent below 1980 real dollars.

Table 1

National Science Foundation:
Funding Levels for Selected Directorates
and Program (Millions)

	Actual	Actual	Proposed	Percent* Change	
	1980	1983	1984	80-84	83-84
Directorate for Mathematical and Physical Science (MPS)	227.0	299.7	364.3	+60	+22
Directorate for Astronomical, Atmospheric, Earth and Ocean Science (AAEO)	218.1	276.2	334.9	+54	+21
Directorate for Biological, Behavioral and Social Science (BBS)	185.7	190.2	223.6	+20	+18
Biological Science	133.3	154.2	182.9	+37	+19
Social and Behavioral Science	52.4	36.0	40.7	-22	+12

*An appropriate price index for these activities probably increases by about 30-35 percentover the period FY 1980-FY 1984.

This Committee is well aware of the series of budget requests, and congressional and NSF reactions to those requests, which have provided this markedly uneven pattern of change over the past several years. I do not wish to dwell on past history or past mistakes, however. I would prefer to talk about the future, and the scientific potential of the NSF social and behavioral programs.

Let me start by spelling out some of the implications, as I see them, of the philosophy about NSF priorities spelled out by Dr. Edward Knapp, the new Director of the NSF, in remarks made just a few weeks ago before the House Appropriations Subcommittee on HUD--Independent Agencies.

In his remarks, Dr. Knapp notes that the substantial increase requested for the NSF in the FY 1984 budget reflects the importance of basic research in laying the groundwork for sustained economic recovery, and recognition of the need to revitalize the research base in the nation's universities and colleges to ensure our continued ability to produce world class scientists and engineers. Dr. Knapp proceeds to quote Dr. Keyworth, the President's Science Adviser, as remarking with regard to our nation's academic institutions that "somehow, we have arrived at the indefensible position of creating the poorest climate for research in the place [the U.S.] that ought to have the best." And finally, Dr. Knapp notes that the NSF program and budget priorities for FY 1984 had as their criteria "the scientific excellence and promise of the activity; . . .and the potential for an activity to contribute to important national economic and productivity goals."

I wholeheartedly endorse the comments of both Drs. Knapp and Keyworth in emphasizing the crucial role played by basic scientific research in achieving national objectives, and the criteria spelled out by Dr. Knapp in describing how program and budget priorities should be set. But I would respectfully submit that the FY 1984 budget request for the social and behavioral science programs does not adequately reflect the application of these principles.

I would like to be sure that the Committee fully understands my position. I support (with considerable enthusiasm) the large increases in the mathematical and physical sciences, the ocean and atmospheric sciences, the engineering sciences, and the biological sciences. These programs represent much needed investments in restoring the nation's technological potential. In an era where our national well-being is increasingly dependent on being at the cutting edge of technology, we can ill afford to continue the previous pattern of halfhearted support leading to technological second-class citizenship.

But these national goals will not be reached by emphasizing the importance of research in the physical and natural sciences alone. Much of our productivity problem has behavioral rather than technological roots, as the Japanese have taught us so well. Much of our capital stock consists of human skills and not machinery and equipment: optimizing the use of these skills in a rapidly changing technological world, and learning how to do a better job of shaping those skills in the first place, are behavioral and not technological problems. And poverty, family instability, crime, inflation, and aging have enormous impacts on individual and national well-being, and none of them represent problems that can be fixed with an improved understanding of the physical and natural world. In short, we depend, as a society, at least as much on advances in the social and behavioral sciences as on those in the physical and natural sciences. In my judgment, the FY 1984 budget request meets neither scientific opportunities nor important national goals in this area.

It is one thing to point to problems where a better scientific understanding of social and behavioral issues could result in important payoffs. It is another to suggest areas where putting resources into basic research has good prospects of helping to achieve these goals, either by enhancing scientific knowledge or by enlightening policy. Let me address that issue, first by spelling out the characteristics of the research methods used in many of the social and behavioral sciences, then illustrating what we have learned in the past from the application of these methods, and finally identifying a number of areas where important scientific progress is possible but precluded by the resource levels in the budget request.

Because social and behavioral scientists are concerned with the analysis of human behavior, they are by and large unable to conduct the sort of tightly controlled experiments that are typical of the physical and natural sciences. There are of course some similarities--astronomers can no more control the movement of the planets than economists can control the behavior of the GNP--both are limited to careful observation and inference from models.

A not unusual sequence of activities by which social and behavioral scientists arrive at generalizations about human behavior involves initial observation, development of concepts and theories, creation of a data base, testing of theory against the data base and subsequent refinement or modification of theory followed by additional empirical tests. More specifically:

1. A (typically casual) observation of some behavioral phenomenon of interest is made--for example, we note that people who are poor seem to have similar characteristics year after year--they are apt to be poorly educated, are likely to be disproportionately black, etc.

2. Those observations lead toward conceptualization and the development of a theoretical structure, which is examined for consistency until some set of surviving, and competitive, theories emerge. For example, the experience of being poor is thought to create a set of attitudes and behaviors that lead to persistent poverty.
3. The state of conceptualization or theory develops to the point where a more rigorous scientific test becomes feasible, and an observational instrument is created. In the social and behavior sciences, the instrument is likely to be some kind of data base, either adapted from an existing source or generated *de novo*. As in the physical and natural sciences, instruments (or data bases) are expensive.
4. The theories are tested on the data base, and are either confirmed or disconfirmed.
5. The process will ordinarily lead to refinement or elaboration of the theory, and may require construction of a new and more powerful instrument or data base.

This description is of course something of a caricature, since the process is seldom so neat. But it does illustrate two important aspects of the NSF role in support of social and behavioral research, and suggests a third aspect of that research which is often misunderstood. First, it highlights the crucial role of support for the generation of data bases. Second, it highlights the importance of support for activities which both precede and follow creation of these data bases,

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And finally, it suggests that social science research is an intensive user of various kinds of instrumentation, and may be little different from the physical and natural sciences in that regard.

Let me digress briefly on this last point. While the social sciences do not have any real counterpart to the linear accelerators or radio telescopes that permit physical science experiments to be conducted and observations to be made with great precision, social science research cannot function effectively with a piece of chalk and a blackboard. One counterpart to instrumentation in the physcial and natural sciences is, of course, the generation of careful measurements on representative samples of behavioral units, preferably followed longitudinally--the scientific data bases with which this Committee is thoroughly familiar. But over and above those instruments, social and behavioral scientists are intensive users of computing equipment, and in fact the availability of computing power has revolutionized social science research.

Let me cite two illustrations from my own university, which has just about the most powerful computing installation in any American university save for two institutions with "super computers" designed to handle complex meteorological and nuclear physics calculations. Of the total funded research usage at the Michigan computing facility, some 35 percent is for research in the social and behavioral sciences. Since roughly 40-50 percent of our science and engineering faculty are in social and behavioral science departments, we are slightly less intensive computer users than physical and natural scientists, but not much less.

The second statistic relates to the distribution cf data tapes from the data archive at the Institute for Social Research at Michigan. During the last decade, the distribution of basic data tapes from this archive, to scholars outside of The University of Michigan community, increased almost twentyfold--at a compound growth rate of over 34 percent per year--and now comes to a total of 67 billion bytes of data annually. These are impressive numbers, and reflect the revolution in research technology that I spoke of earlier.

Let me illustrate the research process that I have described above with a concrete example. During the 1960's and 1970's, repeated observations on the size and characteristics of the poor and welfare-dependent population in the U.S. suggested that we were becoming a nation with a permanent underclass: the fraction of households below the poverty line dropped steadily throughout the 1960's, but the decline came to a halt in the early 1970's and continued at about the same level throughout the rest of the decade. The poor could generally be characterized as disproportionately less well educated, disproportionately black, disproportionately old, and disproportionately female. This series of observations, derived from cross-sectional surveys conducted by the U.S. Census Bureau, gave rise to the notion that a "culture of poverty and dependency" was creating a permanent underclass of something like 10 percent of U.S. households.

Starting in the late 1960's, the then Office of Economic Opportunity started a long-term study of poverty and dependency. The study, which consisted of careful measurements of income and individual characteristics thought to be associated with income change, continued throughout the 1970's and the 1980's. The design of the data base was unique, in that the same individuals have been followed since the late 1960's, thus making it a longitudinal panel rather than a series of repeated cross-sections of individuals.

What has this study shown about the nature of behavioral theories of poverty and dependency? First, virtually every stereotype about the poor and dependent population of the U.S. has been shown to be wrong. Second, this study has demonstrated that achieving a solid understanding of behavioral processes, and thus a solid foundation for the advancement of scientific understanding, will often require data bases designed to follow individuals or other units longitudinally through time. One of my colleagues expressed that thought in the title of a recent paper--"The Dynamics of Poverty and Dependency: Or Why Everything You've Ever Learned from Cross-sections is Likely to be Wrong."

I can summarize the results of the poverty study as follows:

1. It is indeed true that the fraction of U.S. households living in poverty, or dependent on welfare, remained roughly constant throughout the decade of the 1970's. The poverty population has been roughly 10 percent of U.S. households during this period, while the dependent population has been roughly 8 percent.
2. It is also true that the poor and dependent are disproportionately less well educated, black, elderly, and female.
3. It is demonstrably not true that the poor and dependent are the same people over time, as the cross-section studies seemed to suggest.

a. While roughly 10 percent are below the poverty threshold each year, over the period of a decade just about a fourth of the U.S. population is below the poverty threshold during at least 1 year out of the 10, while less than 1 percent (to be precise, 7/10 of 1 percent) is below the poverty threshold during every one of the 10 years.

b. While roughly 8 percent of the population received welfare each year during the decade, fully 25 percent of the population were on the welfare system for at least 1 year of the decade, less than 1 percent (again, precisely 7/10 of 1 percent) were dependent on welfare all the time.

The upshot is that any theory of poverty and dependency has to account for the fact that there is enormous turnover in the poor and dependent population, rather than constancy. It may be true that "the poor are always with us," but they are largely different people from one year to the next, a finding with obvious implications both for models of behavior and for the formulation of public policy.

I would like to turn now to a brief discussion of research activities that seem to me of the highest priority, and which I judge to be impossible to support within the budget constraints in the FY 1984 recommendation for the social and behavioral science areas.

First, let me note that it is a welcome change to see a budget request which contains significant increases for research programs in these areas. The budget will permit continuation of a number of highly important programs, including maintenance of several high priority data bases. These include the General Social Survey, the Panel Study of Income Dynamics (which is the data base I described just above), and the National Election Studies. In addition, a set of essential activities of different sorts, consistent with the framework that I have described above, are also able to be supported within the FY 1984 budget request. But there are a number of areas in which additional resources would permit research that is both highly important in scientific terms and compatible with the Administration's objective of supporting research with the potential for furthering important economic and other national goals.

Saving Behavior

Public policy has over the last several years been framed around an implicit theory of saving behavior--that increasing the after-tax rate of return to saving will strongly stimulate saving and, thereby investment and economic growth. Public policy concerns over a number of years have been informed by a second characteristic of prevailing theories of saving behavior--that people will dissave (or save less) as they age, especially after retirement, and that the changing age structure of the population will create a severe shortage in the supply of saving to finance investment.

The interesting thing about all theories of saving behavior is that none of them can be tested on a data base which has any real prospect of solidly confirming or disconfirming them. Most theories are tested on aggregate time-series data, which results that everyone regards as interesting but highly problematic for reasons that are well understood. Some tests can be made on a more powerful instrument--measurements of individual-level saving, but these tests are bedeviled by the twin problems of severe measurement errors and the absence of longitudinal data on the same individual or households over time.

Generating an adequate longitudinal data base to measure saving at the level of individuals and households is an extremely expensive instrument to create--it might well cost a minimum of 10 million dollars over half a decade. But the profession has probably invested 10's of millions and thousands of professional man years on that important topic alone, in elaborate and elegant forms of guesswork carried out on bodies of information that everyone understands to be inadequate to the task. Generating a data base that has at least a reasonably good prospect of changing inventive conjecture into solid scientific knowledge seems to me a large payoff both in scientific and policy terms.

Nonmarket Activities

Social scientists of all persuasions, principally economists and sociologists, are beginning to recognize that an important element of both material and societal well-being relates to activities that are conducted outside of organized markets for goods and services. The idea is much broader than the so-called underground economy: it extends to the way in which individuals and households use all of their available time, and other resources, to produce a set of tangible goods and services and ultimately a flow of psychological satisfactions or utilities. A unifying paradigm is beginning to emerge in this area: available human time, in conjunction with various kinds of accumulated "capital stock" which influence the effectiveness or efficiency with which time is used, is conceptualized as the ultimate constraint on well-being.

Both conceptual development and empirical implementation hinge on the continued availability of periodic measurements of the way time is used by individuals and households. Such measurements are expensive, and only two have been obtained in the past --a not very satisfactory one in 1965, and a substantially better one in 1975. Proposals to continue this program have been extensively reviewed within the NSF, but resources have prevented a set of measurements originally scheduled for 1981. This area of work, incidentally, has had interesting spin-offs in quite unexpected directions--it turns out, for example, that studies of how time is used at work provide an important insight into the productivity puzzle in the market sector of the economy.

Organizations and Productivity

Social scientists have been puzzling for about a decade on the causes of the productivity slowdown in both the U.S. and much of the Western world. One problem is that we have very little capacity to understand the way in which private business firms organize their productive activities to produce outputs from various kinds of inputs. The basic difficulty is that the only production data that have any generality is obtained for accounting purposes by the U.S. Census Bureau; the data are not accessible, except under severe restrictions, to academic or other users, and are limited in important respects.

Not only is there no good publicly accessible data on the characteristics of firms, but there are no generalizable data at all about organizational structure--hierarchy, incentives, communication processes, etc. When we are all increasingly convinced that part of the productivity puzzle lies in the domain of organizational psychologists and sociologists, it is unfortunately true that we have no systematic measures of organizational variables in a representative sample of business firms, let alone a combination of relevant economic and organizational measures. In the absence of a major investment in what will probably have to be a longitudinal data base, it is entirely predictable that we will be very little better off 10 years hence than we are now.

Families

The American family is undergoing dramatic change in the composition and duration of familial relationships. We know quite a lot about the quantitative characteristics of these changes, based on extensive demographic data and models of marriage, divorce, fertility, etc. What we know virtually nothing about is the change in the bonding relationships between family members that existed when those structures were relatively stable and the ones that are emerging now. What do these changing patterns do to the environment in which children are raised? What is the effect of rising female labor force participation, especially among mothers of young children, on both family relationships and child development? What are the consequences of these changes for the ultimate well-being of individuals, given that an important element of well-being is known to be related to the type of family structure in which individuals are embedded? These are not normative questions, where interest lies in whether the emerging arrangements are better or worse than the older ones. Rather, they are important behavioral issues, where we need to understand the personal and societal consequences.

Aging

We are all aware of the looming demographics--the dramatic change that will be taking place early next century in the age structure of the U.S. population. But again, we know very little about the experience of aging, and how that has changed as first public health and then medical technologies have extended life expectancy. We have learned enough to know that some major stereotypes about aging are mainly wrong--older people do not lose capacity as was once supposed, but are apt to atrophy as their life-styles are disrupted and their sense of social purpose becomes eroded.

Perhaps the best illustration of our lack of imagination on this issue, due in part to our lack of knowledge, is that the present U.S. retirement age of 65 represents a standard that dates from the time that Bismarck set up the German system of old age security, just about a century ago. At that time, most people didn't retire at 65 because they were already dead, and the few who reached 65 were thought to deserve a well-earned rest from a lifetime of arduous labor. But life is not quite like that in the 1980's, and both our social/behavioral and biological knowledge about the nature of the aging process is grossly inadequate to the task.

Learning

In an age where nine-year olds routinely outmaneuver their parents at computer games, it seems hard to believe that we cannot greatly improve both the pace and the richness of the learning experiences provided to our children. We have begun to understand that very young children are much more able to understand numerical concepts than the conventional wisdom had previously dictated. There are obviously major gains to be made here, but they will not come without basic research in areas like cognitive processes and applied research in the dissemination of effective techniques.

This brief and illustrative summary of areas in which significant progress would be possible with substantially enhanced resources is obviously a partial and highly idiosyncratic array. If 10 other social and behavioral scientists addressed that question before this Committee, the number of areas where resources would produce results would be expanded greatly--perhaps not tenfold, since there would be some overlap, but probably at least fivefold.

In addition to being partial and idiosyncratic, the above list is characterized by my own perception that a central ingredient in scientific advancement is that talent, skills and resources must be put into the measurement of behavioral phenomena in order to make cumulative progress. Thus many of the issues that I address are at a stage of development where a carefully designed data base is almost a precondition for significant advance. These measurements often need to be carried out in such a way that they trace the process of change by following identical units over an extended period of time. Such measurement instruments--longitudinal data bases--are relatively rare in the social and behavioral sciences, but they are increasingly coming to be recognized as the only effective way to understand the dynamics of change.

They are also very expensive, they require a long-term commitment to a program of work, and they have the interesting property of becoming more valuable scientifically the longer they accumulate over time.

Summary

To capitalize on all of the research areas with significant potential to expand scientific knowledge and to provide socially useful products would require some multiple of the resources contained in the FY 1984 budget request for the social and behavioral science programs. That objective is unrealistic, certainly in the short-run, but I believe that recognition of this potential should set the tone and objectives toward which these NSF programs should be moved. Last year this Committee recommended a very sizable enhancement of the Administration's original budget request, and I would urge you to do no less this year. But I would be reluctant to see any reduction in the very real need that I believe has been demonstrated in the other basic research programs of the NSF, and would therefore urge that increased support for the social and behavioral science programs come from a modest augmentation to the overall budget request.

Finally, let me add one brief note on the FY 1983 budget for the NSF. Last year this Committee recommended an increase of some 18 million dollars in the NSF Social and Behavioral Science Program. Four other congressional committees that deal with the NSF also recommended increased support for these programs--three committees recommended an additional 5 million dollars, and a fourth recommended an additional

9 million. As this Committee knows, no authorizing legislation was passed last year because of a jurisdictional dispute in the Senate, hence the Appropriations Committee Conference action became the NSF appropriation and authorization. The Conference Committee bill added funds to the Administration budget request, but there seems to have been some confusion about just how much was added and for what purposes. In any event, despite the independent actions of five House and Senate committees which added between 5 million and 10 million to the social and behavioral science programs, the end result--the weighted average, if you like--was a net increment of 3 million dollars to these programs. I have never understood the arithmetic which produced that result, but the facts are not in dispute.

During the budget discussions last fall, I was informed by staff from the Senate Appropriations Committee that there was a possibility that some funds originally earmarked for one of two alternative NSF programs might become available for other uses, pending a decision on which of the alternatives to pursue. If that situation in fact exists, and if there are resources which have not yet been finally allocated within the NSF budget for FY 1983, I would urge that they be made available to the social and behavioral science programs, in keeping with what seems to me to be both scientific priorities and a clearly articulated congressional preference.

Thank you for your time and attention.

Mr. WALGREN. Dr. Leibowitz.

STATEMENT OF DR. HERSCHEL LEIBOWITZ, PENN STATE UNIVERSITY, ON BEHALF OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION AND THE ASSOCIATION FOR THE ADVANCEMENT OF PSYCHOLOGY

Dr. LEIBOWITZ. I want to thank the committee for the opportunity to be here. It is an honor to share my ideas with you. I have a written statement which you have for the record. I also prepared some comments which are based in part on what I heard this morning which are intended to supplement the comments of Dr. Juster and Dr. Knapp.

I think we all agree as to the importance of science to the nation. The quality of life, the survival of our freedom depends on whether we know the fundamentals of science.

I would like, with your permission, to submit a paper I just wrote on this for a lay audience, outlining the importance of research for the university, which I think may be relevant to the committee's deliberations.

Mr. WALGREN. With no objection, that will be made part of the record.

[The paper of Dr. Leibowitz follows:]

The Need to Know

Evan Pugh Professor Pleads the Case For Research

By Herschel Leibowitz

Whatever the limitations which trammel inquiry elsewhere, we believe that the university should ever encourage that continual and fearless sifting and winnowing by which alone the truth can be found.
(Excerpted from a celebrated 1894 University of Wisconsin Regents' report)

Research is neither dull nor formidable. It is exciting, challenging and fundamental. And it is one of three primary missions of any university — ours included.

In addition to teaching and public service, it is our responsibility to discover new knowledge. That's hardly news. What isn't always so apparent is the unique role played by universities in research, its interrelationship with our other obligations, and its critical importance to society.

Whether one speaks of health care, energy, national defense, education, or government, knowledge of fundamentals is essential for the intelligent management of our natural resources. Breakthroughs in science and technology have become so frequent that we tend to take them as a matter of course. The development of polio vaccine, computers, television, jet airplanes, transistors, satellites, and more have enriched and will continue to enrich our lives. What is not generally appreciated is that the fundamental research which was a prerequisite to these applications was provided, for the most part, by research from the university environment. This misperception is probably related to the fact that the public media emphasize the more newsworthy end products.

But developments in technology and their societal applications (including, but certainly not limited to those mentioned) normally occur only after many years of effort aimed at increasing our knowledge of the fundamentals of nature. This basic research is not motivated by potential applications, society's needs, or profit, but primarily by the intellectual curiosity of the scholar.

The inventors of the electronic computer in 1946 could not have been aware of the many impacts their invention would have on our lives in the 1980s. Indeed, even the foresighted founder of IBM, Thomas Watson Sr., was convinced that computers were not a profitable investment [*Belden & Belden, 1962*].

Of course, some basic research is carried out in industry. Larger corporations, such as IBM, commit a percentage of their income to fundamental investigations. But there are differences between university-based and industry-based research. One important difference follows from the potential delay between research activity and its application or payoff. Industry is required to show a profit, and this naturally limits the nature and magnitude of its basic research programs. In the university there are no deadlines. Any contribution is highly desirable if it increases knowledge, aids in deciding among alternative theoretical interpretations, or helps clarify thinking. The University and industry each play an essential role — universities are in a unique position to support long-range investigations of fundamentals, while industry can best translate this information into products and services to be used in our daily lives.

"Basic science is the effective vehicle to move industry from one generation to another" [*Crawford, 1981 meeting, American Association for the Advancement of Science*].

This mutually beneficial cooperation between university and industry is essential to an industrialized society; each plays a unique role which complements the contribution of the other. The post-war success of Japanese industry is attributed in part to the efficient working relationship between industry and university. And in the United States, the National Science Foundation, recognizing the mutually supportive roles played by government, university, and industry, recently initiated a program to improve industrial-academic cooperation.

Research also interacts with other functions of the university. Everyone recognizes the importance and central obligation of teaching. Research and teaching are considered by some to be alternative and even antithetical functions. They are, on the contrary, intimately related; each is mutually beneficial to the other, and the best researchers are frequently the best teachers. Because they are literally on the frontiers of knowledge, their enthusiasm and curiosity are communicated naturally to their students. On the other hand, it is possible for a

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Research

(Continued from page 20)

teacher with excellent technique to be popular, to obtain high ratings when evaluated by students, but at the same time to communicate outmoded and even misleading information.

I was fortunate to have studied with a professor who was universally admired by generations of students because of his teaching skills and his sincere desire to help us learn. One of his courses was in a field in which he had pioneered. The material presented in his lectures was literally unobtainable elsewhere. Highly paid senior executives could often be seen absorbing his wisdom along with the eager young students. More than thirty years later, I look back on this course as a highlight of my graduate training.

This same professor also taught a different course with comparable interest, skill, and enthusiasm. As a student I was equally impressed with both of his courses, but I later learned to my dismay that the second course was woefully out of date. He had taught us material that would have been appropriate as history but which did not take into account two decades of progress in the field. In the first course he was active in research himself, but in the second he was relying on his knowledge of the research of others and was not aware of later developments.

The lesson from this experience is clear. A teacher who is not also an active scholar may inadvertently mislead his students and do a disservice to the university's educational responsibilities.

Dean Mark Ingraham of the University of Wisconsin assigned first priority to productive scholarship. He reasoned that if his faculty were in the forefront of knowledge their teaching would be adequate. Ideally, of course, we would prefer that all faculty be productive scholars, be aware of the state of the art in their fields, and be able to communicate with students as well as to motivate if not inspire them. There are such individuals on every campus, but their numbers are few. Dean Ingraham's assumption was that if we emphasize scholarship, we are in a safer position than if we assign the highest priority to teaching technique.

One frequently hears that a university is "great" or that an institution is rated among "the top 10 or 20 in the country." These evaluations are not based on teaching. On the contrary, the national and international reputation of an educational institution is determined primarily by the quality of the research and scholarship of its faculty. Furthermore, productive researchers attract not only students but also funds.

Since shortly after World War II the federal government has provided generous support for research in universities. There is probably no research university in this country for which government grants and contracts are not a major budget item. These awards are made on the basis of research accomplishments and scholarly potential. Productive researchers, particularly in the sciences, can attract significant financial support from government agencies and private foundations. Penn State currently receives approximately $67 million annually from the federal government. This corresponds to 74 percent of the research budget and 17 percent of total University operating funds (excluding auxiliary enterprises).

The theme of this paper is the mutual interdependence of the university's obligations — teaching, research, and public service. These are not independent or even parallel functions, but rather three modes of discharging our obligations to society. It is remarkable how many examples of this mutual interdependence can be identified. Not only does research aid teaching, but teaching in turn has a stimulating effect on research.

It is our duty as faculty to continually question the state of knowledge in our fields. This is accomplished by a variety of means, including publishing, presenting research reports to peers, and consulting with government and private groups. Such activities provide a welcome test of our knowledge. Our confidence in the value of a theory is enhanced when it is accepted by peers or when it works in the real world. Students play a vital role in this process by questioning and challenging their teachers. An inquiry from someone who is not so familiar with the subject matter can pose a very penetrating question which serves to uncover weaknesses in our own understanding.

Provost Edward D. Eddy characterizes the university as analogous to a three-legged stool. Over- or underemphasis of any of our obligations — teaching, research, public service — interferes with the ability to serve our students, with progress in scholarship, and with the effectiveness with which we meet our obligations to the public that encourages and supports our vital and unique role in society.

THE AUTHOR: Herschel W. Leibowitz might have become a Penn Stater in 1942, but his admissions application was late, so his alma maters are Penn, Columbia, and the U.S. Army, not to mention the universities of Munich and Freiburg (compliments of a Guggenheim Fellowship and a von Humboldt Senior Scientist Award). He has taught at MIT and the universities of Wisconsin, Michigan and Florida; was manager of behavioral sciences at IBM, and joined Penn State's faculty in 1962. Leibowitz keeps his body in shape by running and his mind in gear with research — and both are as natural to him as breathing. Recognizing his significance as teacher/scholar, the President appointed him Evan Pugh Professor of Psychology in 1977, a designation that puts him in the distinguished company of thirteen others similarly named to recognize "the importance of research in maintaining quality and progress in the work of the University."

Dr. LEIBOWITZ. I would like to observe that the National Science Foundation has, in my experience, which goes back 27 years, done a truly excellent job. Some of us oldtimers remember back in the fifties doubts about the government supporting research. These were not justified. NSF played a unique role in supporting research.

The third point I have is one that supplements some of the comments this morning regarding the role of behavioral sciences and its importance to society. Historically, each discipline has a period when it is most productive. Physics and physiology were most productive in previous centuries; the first part of this century, and the latter part of the last century were very productive for physiology.

Because science is hierarchical, behavioral science was not possible until recently. Perhaps the committee is aware the first psychology department was founded only a century ago. We had to wait until the other sciences, physiology, biology, physics made possible techniques and methods to do our experiments.

We have seen in this century an increasing contribution from the behavioral sciences. I brought material with me which I would be glad to share with the committee. The bottom line is that this material, I think, supports the statement that we have really made progress in the behavioral sciences.

We made it because I think the time was ripe. We had the concepts, the techniques and the backing of the Federal Government. Coupled with this oppportunity to continue our progress, there is an increased societal need for behavioral sciences.

You mentioned that very articulately. Dr. Juster mentioned it. I would like to—as Dr. Juster said, any of us could give examples from our own field. I would like to mention a few from my own field, which is experimental psychology.

We have interacted in experimental psychology with the engineering sciences to try to solve some societal problems. Taking an example of one which was very successful, aviation safety is truly remarkable. If you look at any data on aviation safety, particularly in the last decade, the achievement is remarkable.

How do we do this? Well, we did this by working with engineers. Engineers provided the jet engines, provided the instrumentation, provided the mechanical techniques to make jet travel possible. However, without the human factors, without the behavioral science, the people who understand perception and learning and motor skills and response, we would not have the safety record we have in aviation today.

This reflects what I think is happening in our society. As we develop machines, as our technology advances, we have to interact with the engineers to use these in a safe and reasonable way. We call this human factors in experimental psychology.

That has many meanings, but the particular use of it here is in an engineering sense to cooperate with engineers, looking at the interface between man and machine, looking at the unit which the man-machine combination represents.

There are other areas where I think we could, and hopefully will, make some contributions. For example, traffic accidents. By any standard, the 50-some thousand deaths on our highways is a national emergency. It's an epidemic of deaths. We have killed more people on our highways than all the wars of our history. What kind of problem is this?

Well, it's a multiple-disciplinary problem. It involves engineering. It certainly involves behavioral sciences. Let's take an example. The engineers have provided us with excellent seatbelts. They have been developed over the years.

We now have seatbelts which, if you invest a few seconds of your time when you drive, could cut down the accident death rate by half. Yet people don't wear them. About 11 percent of the people wear seatbelts. This is a behavioral problem, not an engineering problem. This is a problem falling within the area of people within my field who are concerned with behavior, with selective probabilities.

We made progress, and I would predict—I don't know the answer to the problem, but I predict when the problem is solved, it will be contributed to immensely by people in the behavioral sciences, of course working with engineers. We need the behavioral contribution.

Look around our society. We see many examples of the importance of behavioral sciences. In health care, many of the problems in health care are not medical. They are behavioral. Overeating, for example, and drug abuse, smoking. We know the medical aspects of this problem. The problems that face us today are behavioral. Fortunately, we have progress in this field which I am hopeful will be useful in the near future.

We find in education we have a revolution in technology with computers. The use of computers depends upon a knowledge of human cognitive processes. We have to know how people think.

We have to know how they gather information from computers. We have to know how they program computers. Those are areas for which the basic science is now being carried on within the behavioral sciences.

Look around this room. We have some very impressive photographs regarding the space program. One of the major problems in space is a behavioral problem of motion sickness. Many of us feel that by combining newer biology, neurology, and behavioral science, we may be able to solve this problem. The point is that the contribution of the behavioral sciences is essential to this approach.

Well, I could go on and on. I know time is short.

Let me just say I think at this period in our history, we have an opportunity to continue our—what I think is a really remarkable achievement in behavioral sciences. Society needs it. We have an opportunity and a need. I hope this brief outline will help you in your deliberations.

[The prepared statement of Dr. Leibowitz follows:]

TESTIMONY OF HERSCHEL W. LEIBOWITZ, PH. D., ON BEHALF OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION AND THE ASSOCIATION FOR THE ADVANCEMENT OF PSYCHOLOGY

Mr. Chairman and members of this Subcommittee, I am Herschel Leibowitz, Evan Pugh professor of psychology at Pennsylvania State University. I received my first grant from the National Science Foundation (NSF) in 1956. Since then I have repeatedly reviewed and evaluated research grant proposals to the Foundation and have been involved in numerous other Foundation activities. This statement is made on behalf of the American Psychological Association and the Association for the Advancement of Psychology which together represent 60,000 psychologists and behavioral scientists.

We are particularly pleased to be able to comment today on the proposed FY 84 authorizations for the National Science Foundation. Members of this Subcommittee are well aware of our deep and continuing interest in NSF and particularly in the Biological, Behavioral, and Social Sciences (BBS) directorate. On behalf of all psychologists, I would like to express our appreciation for your support of the behavioral and social sciences despite repeated attempts by the Administration and some members of Congress to fund these sciences at a disproportionately low level in comparison to other areas of science.

The NSF in the past has represented the best possible contract between science and the federal government in support of basic research in all fields. But this contract has been violated by the Reagan Administration's attempts to designate particular areas of research as being of lower priority for support.

Other witnesses who have appeared before you during these hearings have described the central role of the Foundation in this nation's basic research enterprise and the necessity of maintaining a strong budget for NSF. Rather than cover this ground again, I would simply like to echo our support for full funding for NSF's FY 84 budget. The 18 percent increase targeted for the Foundation is a gratifying signal that the Administration recognizes the value of basic research and shares in the scientific community's confidence that strong basic research activities are a key element in maintaining our status as world leaders in science and technology.

Partisan Research

Just as the proposed 18 percent increase for NSF as a whole is a signal, so may the proposed budget for behavioral and social science research be interpreted in terms of the Administration's intent. But it is a substantially less positive signal that is being transmitted. The proposed FY 84 budget for NSF once again is an attempt to establish a hierarchy among the sciences, with behavioral and social science research receiving far less than an equitable share of the proposed increase for the agency's overall Research and Related Activities budget. This is a particularly critical issue because these areas of research have already borne more than their share of budget reductions since FY 80, the last strong year of NSF funding in these sciences.

We estimate that an increase of 32.2 percent (or 10.9 million) over the FY 83 budget is required to restore the Behavioral and Neural Sciences division to a level of funding comparable to FY 80.* But this division is slated for an increase of only 12.2 percent (from $33.8 million in FY 83 to $37.9 million in FY 84). Within this division, there is an even more disturbing proposal to limit the psychobiology program to an increase of only 2.7 percent (from $3.7 million in FY 83 to $3.8 million in FY 84). Yet we estimate that an increase of 48 percent (or $1 million) is needed to restore the program budget to a level comparable to FY 80. Similarly, the Social and Developmental Psychology program would change only 4.7 percent (from $2.1 million in FY 83 to $2.2 million in FY 84) if the Administration's budget is adopted. But because of recent budget reductions, a 90 percent increase (or $1.9 million) would be required to restore this program's budget to its FY 80 strength.

Instead of restoring these programs, the Administration's proposals would have the effect of further reducing NSF support for the behavioral and social sciences because the increases fall below the rate of inflation. Only budget proposals for the Neurobiology program and the Social and Economic Sciences Division approach parity with the Foundation's other areas of research.

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*This, as well as subsequent estimates, is based on a 5 percent per year inflation factor.

Neurobiology is targeted for a 16.3 percent increase (from $11.2 million in FY 83 to $13.0 million in FY 84) and Social and Economic Sciences are targeted for a 17.7 percent increase (from $19.8 million in FY 83 to $23.3 million in FY 84).

For the sake of comparison, it should be noted that several other areas of the NSF Research and Related Activities budget are targeted for increases that are disproportionately higher than the 18 percent increase proposed for NSF as a whole. For example, Mathematics and Physical Sciences is slated for a 21.5 percent increase; Astronomical, Atmospheric, Earth and Ocean Sciences would receive a 21.3 percent increase; and the Antarctic program would receive a 22.7 percent increase.

It is one thing to establish priorities *within* a particular area of research. But this budget proposes to establish priorities *among* the sciences, thereby creating a partisan mission for NSF. The scientific community as a whole has consistently opposed efforts to politicize research support in any area of science. One example is the following excerpt from the National Science Board's "Statement on Social and Behavioral Sciences":

> The National Science Board believes that support for the social and behavioral sciences, as with all sciences, should continue to be based on criteria of research quality as judged by rigorous critical standards. The Board believes it is imperative to have resources adequate to mount a balanced program. Such a program must include maintenance of large data bases, improvement and strengthening of research methodologies, and provision of opportunity for innovative investigator

> initiated projects. The long-range interests of the country require a continuing base of adequate support of the social and behavioral sciences so that the research base and intellectual vitality the United States has established in these fields can be maintained and increased.

The entire statement by the Board is attached.

The Administration's proposed FY 84 distribution of funds also conveys a message that research in these areas is of less importance to the national interest. This message contradicts the numerous expressions of bi-partisan congressisonal support for behavioral and social science research that have appeared in committee report language and floor statements in the past several years. It also overlooks the numerous breakthroughs that have been made in these sciences. Following are just a few examples of the contributions that have resulted from work in the behavioral and social sciences:

o Studies have been undertaken by psychologists and others on why people affiliate with particular groups. This has implications for understanding a variety of important social phenomena, including recruitment and retention of individuals in military organizations, "burn-out" among individuals who work in stressful settings, and the problems that newcomers encounter when they enter unfamiliar groups (for example, "mainstreamed" students in new classroom settings, "token" women and minority persons in new work settings). These studies have great potential for application in military and industrial activities.

- NSF studies have contributed significantly to basic knowledge about the nature and determinants of constructive and destructive processes of conflict resolution. This knowledge has been used widely in training teachers, administrators, negotiators, mediators, diplomats, etc. in how to deal with conflict constructively rather than destructively.

- Research on a relatively fundamental topic--identifying and measuring human motives--has had remarkable applicability in the hard-headed world of American business. In particular, the achievement motive (measured by special techniques developed over the years by psychologists) plays a large role in promoting successful entrepreneurial behavior.

- NSF has also funded extensive research on the leadership motivational patterns which lead to success in managing large complex organizations. This empirical information has been considered of great value in selecting and training managers for a number of U.S. corporations. It also has been extensively utilized by the U.S. Navy in identifying characteristics that lead to success among officers at different levels of responsibility. Training courses have been developed by psychologists to promote such patterns and other competencies needed for success among officers in the Navy and major corporations.

- The search for the location in the brain where learned information is stored has been long and elusive. Richard Thompson and his colleagues at

Stanford University believe they have localized a brain region involved in the storage of a specific memory. The cerebellum has been known for a long time to be involved in control of motor behavior, but was not suspected to be specifically involved in memory. Thompson's studies are the first demonstrations that a specific bit of learned information may be stored at a discrete site in the brain. These discoveries provide the basis for further investigations to localize other sites of memory storage and to understand the basis of learning pathologies.

o Computers have been traditionally designed and used for scientific computations that involve complex but well defined processes. Recent computer research has led to new approaches and uses of computer systems known as "expert systems." Typically, an expert system will follow problem-solving procedures used by human experts to assist non-experts in solving complex problems in specific knowledge-based areas. To be useful, an expert system must have a knowledge base and the ability to manipulate that knowledge base. Considerable progress has been made in advancing the state-of-the-art of expert systems research on a number of fronts. At Stanford University, for example, a team of researchers led by Edward Feigenbaum has developed expert systems that can aid in medical diagnosis, formulate rules of mass spectrometry, and analyze data in protein crystallography.

Basic behavioral and social science research will continue to play a vital role in addressing many of the long-range issues that face this country. This was affirmed in Senate testimony presented last year by Dr. E. Margaret Burbidge, president of the American Association for the Advancement of Science, who stated:

> It bears emphasis here that many of the nation's problems dealing with energy, the environment, health care delivery, productivity and economic development call for continued research in social and behavioral sciences as well as research in engineering and the physical sciences. Equally important, they call for cooperative and collaborative research among social, natural and engineering scientists and demand a strong research base in all these areas. Neglecting -- or handicapping -- entire fields of science will have serious negative impacts on our ability to meet the challenges of many of our most pressing problems.

New Director for BBS

In addition to setting budget targets for the National Science Foundation there is another aspect of NSF activity that warrants this Subcommittee's close and immediate attention: I am referring to the recent dismissal of the director of BBS and the search for her replacement. Our specific concern is that political beliefs, rather than competence, will be the chief criterion for becoming appointed to that position. We believe that the BBS director was asked to leave for political reasons, and that candidates for the job will be evaluated on similar grounds. This practice again raises the spectre of partisan research because it represents the inappropriate injection of politics into activities where scientific considerations traditionally determine goals and directions of research.

The presence of politics clashes with scientific values. We are urging Congress to uphold those values by using every possible means to encourage NSF to select a new BBS director on the basis of individual expertise rather than ideology. This Subcommittee should maintain an active oversight role in the selection process.

Politicization of the BBS directorship would be especially detrimental to the behavioral and social sciences. As noted above, research in these areas has been deemed as a low priority by the same Administration that will be making the appointment. Under these circumstances, we anticipate that, unless Congress intervenes, the Administration's appointee for BBS will uphold this policy. The vulnerability of the behavioral and social sciences to disproportionately lower support would be increased rather than alleviated.

In Summary

We are asking members of this Subcommittee -- and Congress as a whole -- to take the following steps to maintain NSF's commitment to nonpartisan scientific inquiry and to strengthen the federal government's support of basic behavioral and social science research:

- Redistribute funds within NSF's Research and Related Activities budget for FY 84 so that all programs receive proportionate increases.

- Monitor the selection process by which a new BBS director is chosen. As part of its oversight responsibility, the authorizing subcommittee should intervene to ensure that candidates for this position are evaluated on the basis of competence rather than political beliefs.

Again, we appreciate this opportunity to testify on these important issues. I would be pleased to answer any questions or provide further information the Subcommittee might require.

NSB-81-288

STATEMENT ON SOCIAL AND BEHAVIORAL SCIENCES AS ADOPTED BY THE NATIONAL SCIENCE BOARD AT ITS 227TH MEETING, JUNE 17-19, 1981

The National Science Foundation (NSF) is by statute responsible for the health of the scientific enterprise of the United States. The social and behavioral sciences are an integral part of that enterprise. During the spring of 1981 the National Science Board gave special consideration to social and behavioral science research activities. It reviewed the history of NSF support in these fields, major contributions of social and behavioral science research through the years, the current status of scientific research issues, the availability of other funding sources, and the current operations of the two National Science Foundation divisions. In addition it has received reports from and interviewed distinguished scientists in these fields.

As in all sciences, NSF's unique role is the enhancement of scientific capability and the development of the tools of inquiry. The Foundation provides the major support for all social and behavioral sciences where the focus is enhancing the objectivity of the sciences and improving the quality of data collection and analysis. Such support in the last decade has led to significant progress in the development and refinement of tools, techniques, and analytic capabilities. As a consequence of these methodological advances, new linkages have been forged among the disciplines and between these sciences and the biological sciences. As an example, substantial progress in cognitive research has been made through the joint efforts of psychologists and other behavioral scientists working together with biologists. This progress, combined with the extraordinary achievments in the neurosciences, gives promise for the future of major new understandings.

Our society is increasingly technologically based, and, increasingly, these technologies draw upon the skills and talents of social and behavioral scientists. In this context, there is a pressing need for the development of rigorous procedures for detecting and measuring both intended impacts and unintended effects. The research results of the social and behavioral sciences address these needs.

The fundamental research supported by NSF underpins and strengthens the mission oriented research programs of other Federal agencies and improves the quality and usage of national statistical information. It also contributes to important private sector activities utilizing economic forecasting, demographic projections, survey research, cost benefit analysis, marketing analysis, and personnel selection and training.

The National Science Board believes that support for the social and behavioral sciences, as with all sciences, should continue to be based on criteria of research quality as judged by rigorous critical standards. The Board believes it is imperative to have resources adequate to mount a balanced program. Such a program must include maintenance of large data bases, improvement and strengthening of research methodologies, and provision of opportunity for innovative investigator initiated projects. The long-range interests of the country require a continuing base of adequate support of the social and behavioral sciences so that the research base and intellectual vitality the United States has established in these fields can be maintained and increased.

June 19, 1981

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Education:

Elementary and secondary education in York Public Schools; graduated from William Penn Senior High in 1942.

1942-43;
1946-48: University of Pennsylvania, B.A., 1948.

1943-46: U. S. Army, 75th Infantry Division, European Theater.

1946: Cours pour Étrangers, University of Paris, Paris, France, three months.

1948-51: Columbia University, M.A., 1950; Ph.D., 1951. Experimental Psychology: Minor, Physiology, Major Professor, C. H. Graham.

Post-Doctoral

John Simon Guggenheim Fellow, Department of Zoology, University of Munich and Max Planck Institut für Verhaltensphysiologie, Germany, 1957-58.

Visiting Scientist, Institute for Perception, Soesterberg, Netherlands, (Summer). Heinemann Stipend, Summer, 1967.

Senior von Humboldt awardee, University of Freiburg, Neurologische Klinik mit Abteilung für Neurophysiologie, 1976-77, 1978.

Department of Ophthalmology, University of Florida, Spring Term, 1977.

Employment:

1951-61: University of Wisconsin; Instructor, 51-53; Assistant Professor, 53-57; Associate Professor, 57-60; Professor, 60-61; Research Associate, Department of Neurophysiology, School of Medicine, 53-56.

1960-62: International Business Machines Corporation: Advisory Psychologist, Bethesda, Federal Systems Division; Manager, Behavior Sciences, Bethesda; Manager, Behavioral Research, T. J. Watson Research Center, Yorktown Heights, New York.

1962-: Pennsylvania State University, Professor, 1962 - Evan Pugh Professor, 1977-.

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Visiting Appointments

Lecturer, University of Maryland, 1960-62.

Visiting Professor of Psychology, Summer Session, University of Michigan, Ann Arbor. Lecturer, University of Michigan. Summer Conference in Human Engineering, 1962.

Visiting Professor of Psychology, Summer Session, Massachusetts Institute of Technology, 1963.

Visiting Scientist, Japan, United States-Japan Cooperative Science Program, Summer, 1965.

Visiting Professor, Florida State University, Psychology, 1972.

Visiting Professor, University of Florida, Psychology (Spring Term), 1977.

Visiting Scholar, University of California, Berkeley, Optometry, 1981, 1982.

Editorial

1960-74: Consulting Editor, *Journal of Experimental Psychology*.

1964-68: Consulting Editor, *Psychological Bulletin*.

Consulting Editor: SCIENCE, 1964-; *Behavioral Research Methods and Instrumentation*, 1970-; *Contemporary Psychology*, 1973-79; *International Journal of Vision Research*, 1959-65; 1974-79.

Editorial Board: *Psychological Research*, (*Psychologische Forschung*), 1965-; *Perception and Psychophysics*, 1969-.

Government and Public Service

Consultant, Veterans Administration, 1959-.

Member, Psychobiology Review Panel, National Science Foundation, 1962-65.

Consultant, Institute for Defense Analyses, 1964-79.

Consultant, Department of the Interior, 1965-67.

Consultant, University of Michigan, Infrared Physics Laboratory, 1967-68.

Consultant, Department of Defense, 1967-.

Organizer, N.A.T.O. Symposium on Image Evaluation, Munich, August, 1969.

Board of Scientific Affairs, American Psychological Association, 1967-71.

Experimental Psychology Study Section, National Institutes of Health, 1970-74.

Consultant, Institute for Environmental Medicine, Natick, Massachusetts, 1970-75.

National Institute of Mental Health Research Evaluation Task Force, 1972-73.

National Research Council Vision Committee: Member executive council, 1973-76. Working groups - Visual Displays, Visual Field and Acuity Standards (Chairman), Misleading Information in Night Visual Approaches, Vision Testing, Simulation.

Scientific Awards Committee, American Psychological Association, 1972-74, 1979-80.

Co-organizer, U.S.-Japan Cooperative Science Seminar on Space and Motion, Honolulu, Hawaii, 1973.

Advisory Board, Applied Research Laboratory, 1973-76.

Consultant, U. S. Air Force, 1978-80.

Sensory Physiology and Perception Panel, National Science Foundation, 1979-82.

Co-organizer, NATO Symposium on Motion Perception, Veldhoven, Netherlands, 1980.

Committee on Human Factors, National Research Council (Working Group on Simulation), 1980-.

American Academy of Optometry, Research Study and Planning Committee, 1981-.

Advisory Committee, Center for Higher Education, Pennsylvania State University, 1982-.

Committee on Visual Performance and Safety, U.S. Olympic Committee, Sports Medicine Division, 1982-.

Honorary and Professional:

Guggenheim Fellow, 1967; Heinemann Stipend, 1967; Honorary Initiate, Penn State Chapter of Phi Eta Sigma, 1972; American Institutes for Research Creative Dissertation Award in Experimental Psychology for 1973 to advisee, Robert T. Hennessy; Senior von Humboldt Fellowship, 1976; Center for Advanced Study in the Behavioral Sciences Fellowship; Society of Experimental Psychologists, 1976; Evan Pugh Professorship, 1977; Cosmos Club, 1977; Who's Who in America; Who's Who in the World; Who's Who in the East; Who's Who in Frontier Science and Technology; American Men and Women of Science; Fellow; American Association for the Advancement of Science, American Academy of Optometry, Human Factors Society, Optical Society of America. Member, International Perimetric Society.

Foreign languages: German, French.

Mr. **Walgren**. Thank you very much, Dr. Leibowitz.
Mr. Wyatt.

STATEMENT OF JOE WYATT, CHANCELLOR, VANDERBILT UNIVERSITY

Mr. **Wyatt**. Thank you, Mr. Chairman, members of the committee. I am pleased to be here with you. Let me say that I am chancellor of Vanderbilt University, having been installed two weeks ago. Before that I spent 10 years at Harvard. While there I was appointed chairman of the advisory committee to the Information, Science and Technology Division of the Biological and Behavioral Sciences at the National Science Foundation, and, before that, was chairman of the task force that recommended its establishment.

I want to speak to you briefly this morning about that program, its past, and its future. I have written testimony that is before you and would also like to call your attention to a report produced late in 1982 from our division that describes the state of the research program. This report is entitled, "Research Opportunities in Information Science and Technology, NSF 82-63."

I think it is clear that the investments of this country in basic research have reached a watershed stage in terms of the technology that is manifesting itself from those basic investments. Unfortunately, it is not only this country that is benefiting from that technological watershed. We face now a real contest in leadership between this country and other developed countries, notably Western Europe and Japan, particularly in the area of information science and technology. In fact, the matter has been characterized in the title of a recent book as *The Real World War* relating to the capacity of this Nation to make wise investments in basic science research and to convert the discovery that results to implementable technology.

The Division of Information Science and Technology at NSF was established as recommended by my task force in 1977. In 1980, on the recommendation of its advisory committee, it became a part of the Directorate of Biological and Behavioral Sciences. It has always been clear that there were strong intellectual ties between numerous other programs in the foundation, that is, mathematical and physical sciences as well as engineering. But it appeared to the advisory committee that the most fruitful, new intellectual thought in information science development might relate to the social and behavioral sciences as well as economics.

This depended to a certain extent on the thought that information science does relate to the human organism, and in order to be useful to human beings, must be compatible. There is another dimension. We now believe that in order to understand better certain significant problems that face the implementation of technology, we need to know more about how biological organisms work and how we might synthesize some of their function in automata.

There are three parts to this program in information science and technology. One relates to behavioral science and linguistics, one to economics, and information technology itself. There is no way to summarize that very quickly.

The report I have suggested be entered into the record is, in fact, an eloquent summary. I won't try to summarize it except to say that there has been some discussion about whether these programs duplicate the activities of other parts of the society. And one debate that continues to go on, I think, is whether information technology research, computer science research, information science research, should be done in the Foundation. Does it not duplicate the activities of the private sector?

My advisory committee convened a panel of 15 that included either the chief research executive or the chief executive officer of private laboratories and Government laboratories. For example, it included Gordon Moore, the chairman of Intel Corporation; George Heilmeyer, vice president for corporate research and engineering at Texas Instruments; Sam Morgan, director of computer science research at Bell Laboratories; and Robert Fossum, the current director of ARPA.

That panel concluded there were several important research problems that should be addressed by NSF that would not be addressed by the private sector for a number of reasons. Those research problems are enumerated in this report. We also convened a group of economists around the notion of the relationship between the emerging information society and its effect on the economics of the world, and particularly the United States. Our economy, of course, is becoming more service oriented as everyone knows, and a large part of that relates to information as a product and as a service, a section which is becoming a larger part of the economy. We managed a conference of world class economists on this question. Now we are funding several studies relating to the economics of information as a product and the relationship between information services and the economy. Some say that the economic forecasts that appear to be so unreliable relate to two issues. One is the information industry at work in the world economy. The other is the inability of current macro models to allow for offshore economic activities, often related to technology.

The final research area that I will describe today relates to behavioral sciences and its possible connection with information technology. I might use a very brief example here of a particular path of research that connects information technology directly with behavioral sciences. Categorization of information for understanding by human beings and use by human beings is a fundamental problem confronting every information processing system. Even the most recent developments in information storage and retrieval—in fact those used by the Members of the House of Representatives in the Congress—require a good deal of human assistance and a good deal of patience in order to be able to get much information from them. A major part of that difficulty lies in the inability of automata (machines) to do recognition and categorization of information. One of the blocking problems in the field of robotics is the recognition of geometric shapes without human intervention. We believe there is considerable evidence to suggest there is something to learn from biological systems.

Until very recently it was assumed that we had to understand the human brain in order to move forward. That is indeed a formidable problem. Although some progress is being made, the human brain is formidably quite complex.

Now we have some evidence from research projects that are being conducted at a variety of places using more primitive forms of biological systems to suggest that pigeons, for example, and other much more simple brains have the capacity to do categorization and discrimination of various kinds of shapes and to be able to generalize shapes. For example, pigeons can be trained to recognize trees in photographs, or fish in photographs, or even people in photographs and can demonstrate an ability to generalize from that.

We understand enough about this now to know that the proposition rests on the ability of the optical system and its connection to the brain to summarize, to simplify, to filter, but we simply do not understand how that works. We believe that by studying some of these primitive biological organisms, we can construct algorithms that might allow us a breakthrough in some of these fundamental problems. Solutions might relate to all aspects of the use of information technology by humans, including manufacturing applications and a variety of others.

The generalized problem is to understand how knowledge is represented in the brain and if it might similarly be represented in a machine; to understand the nature of learning, how a biological organism learns simple things and perhaps to synthesize that in machines; and to understand the principle of selective omission of information, a principle that is clearly at work in the act of basic biological organisms as they categorize information.

This, of course, is just one path of activity that we believe is important. I could try to summarize others. I won't take your time. We have the report that I have suggested that summarizes that. We have a forthcoming report in preparation that will describe as nearly as we can, a whole spectrum of problems relating to information science and technology, communications, and engineering from a panel convened several weeks ago. The report will present a menu of research problems from all parts of the National Science Foundation that relate to this general area. I would expect that an early draft of that report will be presented soon to the National Science Board. I am sure this committee would be interested in its findings.

I am here both to inform and to ask. In 1977, my committee articulated three needs. One was the program in basic research that we think is going quite well. The second was a mechanism to assemble facts and analyses so that policymakers and other users of information could reach informed judgments about issues affecting scientific and technical information. Third was a program to encourage training of scientists and nonscientists in the use of science information systems.

The budget we recommended for the first full year (1978) was $11 million. The actual funding for the division in 1978 and over all the years since has been about half that. The high occurred in fiscal year 1981 at $5.9 million. This year's level is $5.4 million. During that time, the research staff of this division has been reduced by over one-third, from 15 to 9 at present. Meanwhile, the proposal flow has increased steadily with proposal quality improving quite rapidly in these three basic areas. It is very clear that these trends are moving in opposite directions. In fact, we are not going to be able to sustain the growth or continue to improve the quality at this level of funding.

It is basic to our belief in the research future of this country that we simply have to make an investment in these fundamental research areas that connect to the behavioral sciences and also connect to the computer sciences or we otherwise will fall behind in an activity that I think is correctly characterized as the real world war.

Thank you very much.

[The prepared statement of Mr. Wyatt, plus Research Opportunities in Information Science and Technology Report, follow:]

TESTIMONY OF JOE B. WYATT

There can be no doubt that America's investments in basic research over the past half century have altered the course and quality of human life for most of the world. During our own lifetimes, the technology resulting from the watershed of scientific discovery enabled by these investments placed America in a position of leadership in the world, a position that has brought prosperity to most Americans and a real sense of responsibility for the world beyond our borders, even for the universe beyond our cosmic boundaries. We have developed the capacity in technology to provide the world with food—a capacity which we continue to refine. We have shown the world the way to industrialization with machinery that magnifies and quickens the productive capacity of human muscle. We have invented and are implementing additional technologies; electronic, biological and others that promise new leverage for the human mind and its biological support system. In doing all this, we have become the principal researcher for the world, continually pushing forward the frontiers of knowledge. But we scarcely have to turn the page of a newspaper or glimpse a segment of television news without seeing definitive evidence that our position of world economic leadership is becoming precarious, that we are in danger of losing what has been characterized in the title of a recent book as "the real world war."

Contemporary information technology, itself representative of a watershed of once seemingly unrelated scientific discovery over the past few years, plays a critical role in the development of the new science and new technology, that characterize this "war." In a forthcoming report to the National Science Board, some new perspectives on the research agenda for all programs relating to information technology in the National Science Foundation will be presented along with some organizational considerations. One part of this report will deal with information science, a relatively new discipline which has natural points of contact with other disciplines such as computer science, engineering, the cognitive sciences, and those parts of the social sciences that are concerned with information processing systems. As a consequence, research in information science and information technology has strong interdisciplinary ties to these fields.

The Division of Information Science and Technology (IST) is a relatively new research program established by the Foundation on the basis of a set of recommendations from an interdisciplinary Task Force appointed in 1977. In 1980, on the recommendation of its Advisory Committee, the Division of Information Science and Technology became a part of the Directorate of Biological and Behavioral Sciences. Although it has always been clear that there were strong intellectual relationships with numerous other programs in the Foundation, including the mathematical and physical sciences as well as engineering, it appeared that the most fruitful *new* thought in information science might relate to the social and behavioral sciences as well as economics. To a very great extent that has been true. In 1982, the Foundation published, in a single report, the findings of three panels convened to examine research opportunities and progress in information science and technology (NSF 82-63).

The report is a useful summary of the intellectual activity—the research problems,—that characterize work in three areas connected to information science: Behavioral Science and Linguistics, Economics, and Information Technology itself. No single report could give a complete review of these fields, and I do not wish to summarize eloquently written summaries, unless you wish me to do so. I would, however, like to describe the framework in which the reports were developed and give one illustration. First, there was the hypothesis that other research programs, including the private sector, were addressing the problems identified. Perhaps the area most commonly tagged with this hypothesis is research in information technology. To address the issue, a panel of fifteen was convened that included either the chief research executive or the chief executive of private and government research laboratories. For example, the panel included Gordon Moore, Chairman of Intel Corporation, George Heilmeyer, Vice President for Corporate Research, Development and Engineering at Texas Instruments, Sam Morgan, Director of Computer Science Research at the Bell Laboratories and Robert Fossum, Director of ARPA. The panel concluded that there were several important basic research problems that were not likely to be addressed by the private sector and that should be considered by NSF. The report describes the problems and the rationale for their existence. A panel of fifteen economists also of international stature from the private sector and higher education, were convened and a conference ultimately held for the purpose of discussing research problems at the intersection of economics and information science. Their report discusses a set of several important problems that include questions concerning the contribution of information as a product in the world economy and the effects of information on productivity in terms of Gross National Product, to mention only two among many. The third report produced by a panel of eleven summarizes research issues at the intersection of behavioral and information science. Perhaps one illustration from this area would be useful to the Committee.

Categorization of information for comprehension and use is a fundamental problem that confronts all information processing systems. The most recent developments in computer-based systems for information storage and retrieval require considerable human assistance (and patience) to recognize patterns in sets of information. The recognition and categorization of simple geometric shapes without human intervention is a fundamental limitation in the field of robotics, for example. We seem to have much to learn from biological systems.

Summarizing recent developments in cognitive psychology, a New York Times science writer echoed the attitude he must have heard in many interviews: "We human beings . . . are concept-making creatures: Unlike any other animal, we have a natural ability to group objects or events together into categories" (New York Times Magazine, January 24, 1982). In fact, however, recent evidence indicates that, at least under some conditions, categorization principles employed by animals are virtually as inscrutable and complex as those used by human beings. Pigeons, for example, have been trained to sort through photographs looking for instances of such categories as people in general or an individual person, trees, bodies of water, fish, letters of the alphabet, oak leaves, and various regular geometrical figures, such as triangles or diamonds. In these studies, the categorizations in question have passed the test for generality with new stimuli. That is to say, after a pigeon has learned to distinguish between a given set of photographs containing trees from one not containing trees, it can be tested with different photographs, to see if the pigeon's principle of categorization generalizes to new instances, as it must if it is at all comparable to those of human categorizations. Some degree of generalization was demonstrated by most subjects in each study, often a high degree by all subjects. Understanding this capability may provide clues to the simulation of cognition by machines.

As long as it seemed that human categorizations are uniquely complex, then the inability to simulate them seemed readily explainable as a corollary of the sheer complexity of the human brain, with its 10^{10} neurons each with multiple connections. The situation alters radically, however, in light of the discovery that animals with relatively small and simple brains, such as birds, also perform these complex categorizations, and that they do so apparently with no greater difficulty than human beings do.

The existence of complex, multidimensional categorization by relatively simple organisms implies that evolutionary processes have discovered and implemented nontrivial algorithms far beyond any existing theory in information science, let alone its implementation. Research along this line might, to begin with, search for the lowest biological level at which present information science loses its ability to account for the observed categorization. At that point, there may be a reasonable expectation of discovering a biological solution to a complex classification task. If these biological solutions can be understood in algorithmic terms, clues may follow to the architecture of highly parallel information processing machines and the structure of what some have called the "biochip." This illustration relates to a larger set of fundamental research problems in information science that include the following:

1. Understanding how knowledge is represented in the brain and how it could be represented in a machine, and the collateral questions of

How information provided by the sensory systems is converted into the abstract forms which the brain actually uses, and

The extent to which artificially constructed information-bearing forms of communication, such as language, mathematics, and music, reflect the internal and structure of knowledge and the (mental or machine) means for employing them.

2. Understanding the nature of learning, with particular emphasis upon the relationship between the properties of the information to be learned and the internal state of the learner. This includes a characterization of the knowledge base requirements of the (mental or machine) learner and processing rules as a function of the knowledge being acquired.

3. Understanding the principle of selective omission of information, and its limitations. This principle is at work in all biological information processing systems. The sensory organs simplify and organize their inputs, supplying the higher processing centers with aggregated forms of information which to a considerable extent predetermine the patterned structures which the higher centers can detect. The higher centers in their turn reduce the quantity of information which will be processed at later stages by further organization of the partly processed information into more abstract and universal forms so that the representatives of inputs to different sensory organs can be mixed with each other and with internally generated and symbolic information-bearing entities. This principle also governs the creation of "abstracts" and "indexes" of text information and it will surely play an important role in robotics and in artificial intelligence applications.

Nontrivial powers of categorization in subhuman animals, like the pigeons in the illustration, provide a rare opportunity for research into the general problem that supplements traditional computer science approaches in a powerful way.

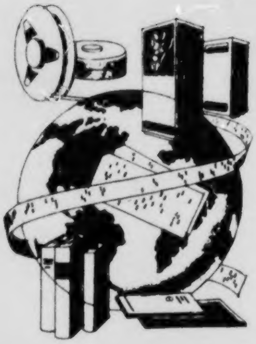
This illustrative path of research inquiry is only one of a number of paths in information science research that link to other disciplines, in this particular case, the behavorial sciences. Suffice it to say that there are numerous other illustrations that further characterize the depth and breadth of the field, its interdisciplinary nature, and the potential benefit of its research findings. I believe you would find the cited report both interesting and enlightening. I expect that you will find the more comprehensive forthcoming report on research in all areas relating to information technology at NSF even more interesting and enlightening. It is clear to those of us that have examined the question closely that the interdisciplinary unions fostered by this new research program are in fact producing new threads of research and discovery that are likely to improve the understanding of the relationship between human thought processes and technological information processes.

My purpose here today is both to inform and to ask for consideration on behalf of information science research. As a prelude to the latter, it is useful to understand some of the history of the Division of Information Science and Technology. The report to the Director in 1977 which recommended the formation of 1ST articulated three needs:

1. A new program to support research in Information Science and its research application;
2. A mechanism to assemble the facts and analysis so that policymakers can make informed judgments about natural issues affecting scientific and technical information.
3. A program to encourage the training of scientists and non-scientists in the use of science information systems operated by the public and private sectors.

The budget recommended for the first need, research in Information Science and its research applications, was $11 Million. Actual funding for the Division during its five-year history has been about half that—the high occurred in fiscal year 1981 at $5.9 Million; this year's level is $5.4 Million. The research staff of the Division has been reduced by over one-third during the past four years. Proposal flow has increased steadily with proposal quality improving rapidly in the three basic research program areas. However, because of the low funding level, research applications in information science and proposals that require instrumentation or the development of sizable prototypes are not fundable. The Division is accomplishing the intellectual goals of interdisciplinary activity that were envisioned by those who recommended them. It is clear from the recent review with all of the research programs at NSF relating to information technology that the 1ST program is a viable and important part of the research spectrum if the United States is to rejuvinate its position of international leadership, a position that now faces serious challenge.

NSF 82-63



Research Opportunities in Information Science and Technology:

- Cognitive Aspects of Information Science
- Information Technology
- Economics of Information

Division of
Information Science and Technology
Directorate for
Biological, Behavioral, and Social Sciences

National Science Foundation

1982

PREFACE

In order to assist it in fulfilling its oversight and advisory responsibilities, the Advisory Committee for the Division of Information Science and Technology of the National Science Foundation has periodically sought the opinion of experts concerning the research opportunities and trends in information science and technology. This advice is particularly important for the Division of Information Science and Technology, because it is new in the Foundation and because much of its research agenda is formulated from the intersection of other disciplines. This volume contains the reports of three special Working Groups which were convened separately over a three year period at the request of the Advisory Committee for that purpose. Each Working Group was chaired by a member or members of the Advisory Committee. Each Group was charged to identify research questions in information science and technology, if any existed, that lay outside the more established disciplines but that could contribute to the understanding of fundamental questions that might foster the development of new knowledge.

Information science is a relatively new discipline which has natural points of contact with other disciplines such as the cognitive sciences, computer science, and those parts of the social sciences that are concerned with the organized, quantifiable, and goal-directed behavior of collections of individuals. As a consequence, information science and the associated technology have strong interdisciplinary ties to these fields. Taken together, the three Working Group reports provide a responsible and broad-gauged overview of information science and technology which shows its relationship to its neighboring disciplines while also clarifying the essential ingredients which distinguish its thematic scientific problems from theirs.

In all respects these reports represent an auspicious beginning—a foundation on which can be built research of lasting value in a society increasingly influenced by the effects of information technology. Each of the reports suggests a research agenda that is rich in content and diversity, and that in most cases can be conceptually translated between the abstract and the real with only modest imagination. For example, one report suggests that fundamental questions relating the phenomena of learning and memory in animals to a theory of "cognitive processes" may infer future bridges to the fields of automata theory and artificial intelligence. Another report recognizes that economists are only beginning to develop theory with respect to the cost and distribution of information viewed as a commodity in a variety of organizational structures—a problem of perplexing dimensions in the social, political, and economic order of the world. The third report confirms that the technology that has raised many fundamental questions by virtue of its rapid and pervasive development is itself a product of research inquiry found in need of more intense basic research in eight general areas. Each of the reports is informative and suggestive in its treatment of the research purview of interest. Each is written in a style that communicates to layperson and expert in different ways, but importantly and effectively to both.

Each Working Group adopted its own procedure for considering its charge and preparing its report. Each Group met at least once in plenary session. The Information Science and Economics Working Group chaired by Leonid Hurwicz held several meetings and conducted a workshop at Northwestern University. The Working Group on Information Technology co-chaired by Paul Strassmann and Richard Tanaka convened its members at the National Academy of Sciences and subsequently conducted small group meetings as its report was prepared. The Working Group on Behavioral and Linguistic Research Bearing on Information Science co-chaired by Duncan Luce and Joan Bresnan held several meetings in Cambridge, Massachusetts and Washington, D.C. as its report was honed to completion.

The participants in each of the Working Groups represented a broad cross-section of distinguished researchers and research directors from business, government, and education. The reports of all three Groups were widely read in draft form and have the benefit of considerable advice from a broad constituency of interest. It is already clear from the research activity in information science and its related disciplines, that the intellectual exchange fostered by the Working Groups has begun to bear fruit.

The opinions expressed in this volume are those of the authors; they should not be viewed as a representation of the field which has been given the formal endorsement of its members, nor as representing the policy or position of the Advisory Committee or the National Science Foundation. But the stature and experience of the members of the Working Groups, and the thoughtful and stimulating content of the reports themselves offer assurance that this volume will offer much of value to the reader whose interests lie in science policy, while the unified view it presents of information science and its research opportunities will act as a stimulant to members of the scientific community.

The memberships of the Working Groups are listed on the following pages. The Advisory Committee has asked me to express its appreciation to each of them for their valuable contribution to which I wish to add my personal gratitude for their willingness to assist the Advisory Committee. Finally, it is my pleasure to acknowledge the splendid work of the Committee members which chaired the Working Groups and to express our joint gratitude to Howard Resnikoff, the first Director of the Division of Information Science and Technology, for the able leadership and imagination which has benefited all of us.

Joe B Wyatt
Chairman, Advisory Committee for
Information Science and Technology

WORKING GROUP ON BEHAVIORAL AND LINGUISTIC RESEARCH BEARING ON INFORMATION SCIENCE

ADVISORY COMMITTEE FOR INFORMATION SCIENCE AND TECHNOLOGY

NATIONAL SCIENCE FOUNDATION

JUNE 21, 1979

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WORKING GROUP ON INFORMATION TECHNOLOGY
ADVISORY COMMITTEE FOR INFORMATION SCIENCE AND TECHNOLOGY
NATIONAL SCIENCE FOUNDATION

JUNE 5, 1980

Gordon Bell
Vice President of Engineering
Digital Equipment Corporation

Robert R. Fossum
Director
Defense Advanced Research Projects Agency

George H. Heilmeier
Vice President
Corporate Research, Development & Engineering
Texas Instruments Inc.

William F. Miller
President & Chief Exec. Officer
SRI International

S. P. Morgan
Director
Computing Science Research Center
Bell Laboratories

Keith Uncapher
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University of Southern California

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John V. Harrington
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Intel Corporation

Lawrence G. Roberts
President
GTE Telenet Communications Corp.

Eric Wolman
Head, Advanced Computing Systems Department
Bell Laboratories

From the Advisory Committee For Information Science & Technology, NSF

Co-chairmen of the Working Group

Paul A. Strassmann
Vice President
Information Products Group
Xerox Corporation

and

Richard Tanaka
President
Systonetics Corporation

Joe B. Wyatt
Vice President for Administration
Harvard University
and Chairman of the Advisory Committee for
Information Science & Technology, NSF

From the National Science Foundation

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WORKING GROUP ON THE CURRENT STATUS OF THE INTERFACE BETWEEN INFORMATION SCIENCE AND ECONOMICS

ADVISORY COMMITTEE FOR INFORMATION SCIENCE AND TECHNOLOGY

NATIONAL SCIENCE FOUNDATION
SEPTEMBER 28-29, 1979
NOVEMBER 6-8, 1980

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Report of the

WORKING GROUP ON BEHAVIORAL AND LINGUISTIC RESEARCH BEARING ON INFORMATION SCIENCE

of the Advisory Committee for Information Science and Technology
National Science Foundation

Abstract

A variety of problems involving the transfer, storage, and retrieval of information have, so far, eluded solution within the framework of current science and technology and yet are readily solved by biological systems. Some seem highly specific to humans, e.g., chess playing and language; others are found widely dispersed among animals, e.g., recognition of complex stimuli, categorizing, and learning. This report reviews some of the main lines of research in the behavioral and linguistic sciences that appear to shed some light on the biological solutions to problems of the abstraction, storage, retrieval, and use of information. Although the specific examples may be somewhat idiosyncratic, the broad outline of the several topics is less so.

Although much current concern with information—its communication, transmission, abstraction, storage, retrieval, and use—arises in connection with physical systems, especially those drawing upon computer and telecommunications technology, the most challenging information handling systems are still biological. They exhibit features of great importance that are not yet well mimicked by artificial systems—e.g., extraction of meaning from text materials, identification of complex objects in complex environments, language processing, coping with imprecise directions or discussion, associative memory, and the like.

Because biological systems often appear to be more subtle and flexible, although less systematic, fast, and patient, than contemporary artificial systems, it is of much interest to try to understand the principles of information processing that are used. Is our ability to recognize all sorts of handwriting and type fonts wholly a matter of programming complexity and cleverness or are there principles involved we do not yet understand? Once the biological strategies are discovered, what impact will they have on information technology? It is easy to suggest an analogy to powered flight—although we understand something of how birds power their flight, it is unlikely that these techniques will ever compete with jet engines. Yet, perhaps, there are biological principles of information processing and storage quite different from any that have been thought of. If so, then when these principles are elucidated and cast in abstract form they will have important hardware and/or software implications.

One important aspect of human functioning, which is possibly related to limitations in the brain, is that many of the brain's special purpose devices appear to be able to perform certain tasks well only at the expense of doing others badly. For example, there is a certain amount of evidence that children with dyslexia are remarkably good at certain kinds of visual-spatial tasks and that many of them draw very well.[2] This may be related to the fact that artificial devices and human beings often differ in what they do best: chess-playing computers play in a style different from humans, in part because they can, in fact, do certain things that the human being cannot do, such as make more calculations of the effects of possible moves. However, the computers seem, as yet, not to respond to or to evaluate more global aspects of positions on the chess board, a human ability perhaps akin to the identification of natural categories discussed below.

What follows is one possible outline of studies directed at the several aspects of information processing in biological systems. The examples are illustrative, not exhaustive, and to some extent reflect the backgrounds of the authors.[1] The topics fall under two major headings: ***problems of representation of information***, and ***principles of implementation***. The representation problem subdivides into questions about the nature of the representations, their storage and retrieval, their control of behavior, and their communication.

THE REPRESENTATIONS OF INFORMATION

Nature of the Sensory Code

One striking finding of peripheral neural physiology and psychophysics is the complex, scrambling nature of the sensory transduction. It is nonlinear with a vengeance, transforming what amount to continuous inputs into stochastic processes—neural pulse trains. And once the transduction is completed, the recoded information tends to spread into various neural circuits of increasing complexity. Two things seem to be clear. First, not all of the transduced information is attended to by the higher processing centers. Second, there appear to be built-in structures that make the organism sensitive to unique configurations of stimulation. As an example, chimpanzees born and raised in captivity are frightened by certain stimuli, such as snakes or dismembered bodies, with which they are unfamiliar.[3] Such work can and should be approached on both a physiological and a behavioral level. The latter is essential: the neural wiring is far too complex for us to have any hope of understanding it without rather precise information about the behavioral capabilities resulting therefrom. We take up these two topics separately: attention and natural categories.

Information Overload and Attention

It is evident that far, far more information impinges on an organism than gets transduced, and far, far more is transduced than is used or stored. How do we and other organisms filter, attend to and selectively store information? What are the strategies that permit rejection of much of the information flow at the expense of minimal cost in errors? What are the developmental aspects of this, both in youth and in aging? One senses that at both the beginning and at the end of life biological systems are less able to deal with multiple sources providing high rates of information than when they are fully mature but not yet old.

A great deal of the work currently classed as "cognitive psychology" is concerned in one way or another with the concept of attention.[4] Attempts are being made to understand shifts of attention both among and within modalities. Even in sensory psychophysics the concept has begun to play a role in accounting for the well known discrepancies in performance when wide and narrow ranges of stimuli are employed.[5] And in vision, behavioral evidence has recently been provided that the locus of attention is separable from where one is looking.[6] Moreover, it is possible electrophysiologically, using microelectrodes in the inferior parietal lobule, to separate the locus of attention from where an animal is looking.[7]

Natural Categories—Psychological Approaches

Given that some selection process must be occurring—both actively and passively—how are the choices of categories made? Clearly, the remarkable prevalence of categorization, appearing at so many levels in the animal kingdom, suggests that it must be the source of important economies in the functioning of the brain.

In one animal example, highly taxing to current models of perception, pigeons have been reinforced for pecking a switch in the presence of a photographic silhouette of a particular white-oak leaf and for not pecking in the presence of silhouettes of leaves from other trees, e.g., maple, tulip, elm. From this training, the pigeon generalizes readily to leaves it has never seen, pecking in the presence of white-oak leaves and not in the presence of non-white-oak leaves. The variety of white-oak leaves is considerable, including variation in the number, depth, and placement of its lobes. Yet there is, to the human observer, a typical form for white-oak leaves, and pigeons evidently abstract this form invariance from a single exemplar in comparison with the leaves of other trees.[8]

As an example of what must happen when a person perceives a natural category, consider speech. To perceive a phonetic category—for example, the p that is present in *split* and absent in *slit*—the listener must integrate into a unitary percept a considerable number of acoustic cues, although these are diverse, widely spread through the signal, and overlapped with cues to other categories in the phonetic string.[9] Yet listeners do integrate, and so recover the categories. Research has shown what this process requires of a listener, and it has uncovered much of the acoustic information he uses for the purpose. But it has not yet provided much insight into the underlying mechanisms; hence, we do not know how to design their equivalents for speech-recognizing machines. Speech recognizers are being produced, but they do not always extract phonetic categories as such. Rather, they represent words as temporally complex indivisible patterns of sound, and, perhaps for that reason, deal only with limited vocabularies. They demonstrate little ability to abstract the common linguistic features when the same word arises in different contexts or is spoken by different people. That we human beings are not so limited may be owing to our ability to recover phonetic categories. It is, after all, precisely those categories that the speaker encodes in the speech signal. Accordingly, they are the true units of the message, capturing exactly the systematic phonetic changes that relate the various tokens of a word to its underlying type and also, by marking syntactic and morphological boundaries, provide information important to processing a sentence.[10] It seems important, therefore, to make these phonetic categories available to speech-recognizing machines, but to do so will likely require a better understanding of how human beings perceive them.

Color naming provides another impressive example of natural categories in human beings. It is also a very good example of cross-disciplinary research, involving laboratory psychophysical studies, neurophysiological studies in infrahuman primates and anthropological studies across cultures.

The problem of color naming was initially approached from a cultural relativism viewpoint. We know that the range of visible color hues from red to blue and of color brightness from black to white is continuous. It is possible, in principle, for cultures to divide and label the color continuum as they see fit. To demonstrate the thesis that psychological differences are associated with terminological conventions, early experiments tested the color memory of English speakers. Colors without simple names were both difficult to name or describe and difficult to remember.[11] Such results were initially interpreted to mean that language does constrain thought, but that interpretation proved to be inverted. Subsequent studies demonstrated that particular colors are not distinctive because a culture has given them names. Rather, colors are given names because they are distinctive.[12]

The evidence comes from several sources. Psychophysical studies[13] revealed that certain 8 to 11 primary colors—including those which English speakers call red, green, yellow, blue, black, and white—have special status in color discrimination tests. Neurophysiological research[14] (primarily on Rhesus, which appears to have color vision identical to human) demonstrated that the visual system organizes these primaries into opponent pairs—red/green, yellow/blue, and black/white. In other words, the organization of color into primary pairs is an innately given biological property of all humans with normal vision, some infrahuman primates, and perhaps lower species. Furthermore, anthropological studies[15] of peoples whose languages contain fewer color terms than English revealed that, in all cases, the "best instances" of the colors named are close to the psychologically primary colors; that these color terms are directly translatable to English. Finally, when memory tests were conducted on people who spoke a language with only two basic color terms, they remembered primary colors best, even though they had no names for them.[16] Clearly, some aspects of color naming are culturally determined: the number of terms does vary. However, the use made of available color terminology is constrained by innate properties of the brain and their relation to information processing, rather than color naming being a matter of pure convention.

Categorizaton by both subhumans and humans suggests that there is a widely dispersed biological solution to the problem of extracting invariances from variable exemplars, a kind of universal pattern classification algorithm. The presence of the solution in such organisms as pigeons further suggests that it requires relatively little cognitive capacity. It seems likely that natural selection has fostered the evolution of perceptual systems that are predisposed to form categories for the classes of objects that are important to survival. The more subtle, abstract, and dispersed these predispositions are, the more profound is the scientific challenge in finding evolution's solution to the problem of extracting invariances.

This work may well be getting close to the point where mathematical descriptions of conceptual representations would be a true contribution to a science of information representation. The trick seems to be to understand the classes of transformation that leave the category invariant. A deep understanding of the nature of categorical perception should help us to design devices capable of pattern recognition.

Natural Categories—Physiological Approaches

We must consider the possibility that at least some natural categories are, in part, pre-programed or even hard wired into the system. Consider, as an example, the recognition of faces. The belief that this skill may be preprogramed arises from the fact that people with severe disorders in the ability to recognize faces have sustained brain damage (to essentially symmetrical regions on both sides) which is remarkably stereotyped from case to case. Although these patients have gross difficulty in recognizing or learning new faces, they can read, recognize colors, and deal correctly with other visual stimuli, a pattern which suggests there is a special system for the learning of faces.[17]

More generally, the study of animal brains physiologically and of accidentally lesioned human brains suggests there are a remarkable number of such highly specialized devices. For example, a large proportion of laboratory-raised cats who have never seen a mouse attacked will attack, just as animals raised outside do, by biting the nape of the neck. If cats that do not attack spontaneously are stimulated in the lateral hypothalamus, they also bite around the head or neck.[18]

There are few areas other than the study of natural categories in animals where one can so readily cross the boundary between the cognitive sciences and neurophysiology. Of course, true experimental study on the language areas of the human brain may never be carried out, and it is unclear the extent to which work with higher apes will illuminate the problem even if they exhibit forerunners of language, as some investigators have claimed. On the other hand, natural categories may constitute a forerunner of at least one aspect of language, naming. Attaching a distinct response to a class of stimuli is the ingredient common to naming by human beings and categorization by subhuman animals.

STORAGE AND RETRIEVAL OF REPRESENTATIONS

Storage

Although there is some dispute, many workers continue to feel the distinction between long- and short-term storage is useful, a distinction which is in some respects comparable to that between "cache memory" and "main memory" in contemporary large computers. To a considerable degree, much of the physiological work on memory has been devoted to long-term storage, whereas the psychological work focuses both on long- and short-term memory.

The work on short-term storage is a blend of empirical and mathematical modeling. The dominant approach has been to assume that short-term storage is in some relatively small number of bins—roughly seven—which can temporarily store materials of varying complexity provided they are properly packaged.[19] The nature of this store—how it is accessed and at what rate, how it is maintained, how it is transferred into more permanent form—has been the subject of many experiments and theories.[20]

Current psychological, as distinguished from physiological work on long-term storage has focused on the coding of meaningful information such as that contained in sentences. It has been known for some time that less than a minute after a sentence is presented, one has virtually no memory for the specific words actually presented; only the meaning is preserved.[21] This has led to the development of formal and quasi-formal languages for representing meaning in memory, with the idea that variations in memory performance can be better understood in terms of variations in meaning representations than in terms of the actual input. Thus the probability of successfully coding a sentence depends more on the number of distinct meanings or propositions in the sentence than on the number of words in the sentence.[22] Further research along these lines may have important implications for the design of higher level programming languages.

Physiological studies suggest that the persistence of stimulus aftereffects occurs differentially in different regions of the nervous system. In primary sensory pathways the persistence of the neuronal response to a brief stimulus is of the order of iconic memory, whereas in certain neocortical regions and limbic structures the neuronal aftereffects may have durations of the order of primary memory.[23]

Insofar as localization of memory processes is concerned, there is evidence that the visual icon may be stored in significant part in the retina and the visual pathways.[24] Data are much less clear as yet concerning possible anatomical-physiological substrates for primary and secondary memory. Structures of the limbic system, particularly hippocampus and amygdala seem critically involved in the processes of longer term storage and/or retrieval of information in both human and infrahuman mammals.[25] Some phenomena of behavioral plasticity resembling simple conditioned response learning can be induced at reflex and even spinal levels.[26] However, cerebral systems—the neocortex and limbic structures—appear to be necessary for the preservation of the normal parametric features of conditioning and for more complex aspects of learning and memory processes.[27]

In biological terms, analysis of the physical-chemical substrates of memory is in its infancy, in that we are only beginning to gain some idea of the brain systems involved. A clearer characterization and localization of these systems and their interactions in the context of information processing is a necessary aspect of the search for the "engram". Mathematical models having at least some of the characteristics of long-term storage and retrieval are now appearing.[28]

Retrieval

Much of the work on retrieval has been concerned with demonstrating that memory failures frequently arise at the retrieval end of the system. Seemingly forgotten information can often be retrieved by reinstating the context in which the information was learned, indicating that context is a particularly effective retrieval cue.[29] Other studies have focused on factors that diminish the effectiveness of a retrieval cue, like multiple connections to the cue.[30]

There is no guarantee that the processes—algorithms and heuristics—that people use with small data bases are of any use with large ones. Sequential searches, for example, make sense with small data bases but are unrealistic for large ones. For these reasons, research on human retrieval from large data bases seems highly relevant to information science.

Learning

Studies in animal learning have recently come to emphasize processes analogous to those of human memory. The term "cognitive processes" is increasingly being used to characterize this general information processing approach to the phenomena of learning and memory in animals.[31] One distinction is between working memory—stimulus information useful for one trial only—and reference memory—information useful for many trials—in analyzing operant learning in the pigeon.[32] (It appears that hippocampal damage selectively impairs working memory in many species.[33]) Others have analyzed classical conditioning (using rabbit eyeblink) in terms of effects of expectancy and "priming" on short-term memory and have developed hypothetical structures for short-term and long-term memory processes in animal learning.[34]

A learning experience is fragile and easily manipulated for a short time after the experience—it can be impaired by electro-convulsive shock and anesthetics and facilitated by certain drugs, hormones and peptides in both humans and animals.[35] On the other hand, the formation of long-term memory in animals can be impaired by substances that interfere with protein synthesis.[36] These consolidation phenomena provide further evidence for a fundamental distinction between shorter and longer term memory processes in animals as well as in humans.

REPRESENTATIONAL CONTROL OF BEHAVIOR

Decision Making and Heuristics

This area is vast and has attracted a great deal of attention by scientists from various fields. Some of the key words are: subjective probability, expected utility, risk, heuristics, information processing strategies, Bayes' theorem, representativeness, etc. There is a long standing tension between optimal approaches, as exemplified by work often called decision analysis, which is based largely on subjective expected utility theory and Bayes' theorem, and empirical results that show not only that many people (including those with decision responsibilities of importance) fail to behave optimally, but that they do not always want to follow the dictates of optimal models. For example, many subjects will order certain pairs of gambles opposite to the amounts they say are equivalent to the gambles individually.[37] The failure to behave optimally could be due to an inability to handle the information processing required, which could perhaps be compensated by artificial devices, but the failure to want to be optimal suggests some basic misunderstanding either by most people or by the scientists analyzing these decision situations.

It is now generally conceded that human subjects, unless especially trained, approach complex decision problems involving chance events by invoking various forms of heuristics inconsistent with either rational considerations or statistical theory.[38] As yet, no very satisfactory descriptive model has evolved.

Motor Control

The study of coordinated movement has been much neglected, certainly by comparison with perception. Yet the problems of movement are just as relevant to information science as those of perception—indeed, the two are mirror images. In movement, as in perception, there is the problem of many-to-one: how does a movement system achieve a particular objective in so many different ways, from so many different starting positions, and under so many different conditions? From the standpoint of purposive control, how can the degrees of freedom in the system be minimized, or even made manageable? What principles determine, in a given activity, which variables are altered and which are held constant? What are the constraints on the system that restrict its operation to activities that are behaviorally useful? How do we solve the fascinating, but not much thought about, problem concerning the relationship between afferent and efferent patterns? Consider, for example, how it might be that the afferent patterns corresponding to the auditory (or phonetic) representation of incoming speech sounds are "translated" into the efferent patterns that produce mimicry. Note that the process appears to be accomplished with very little trial and error and, in the adult, with such speed as to imply a mechanism that is both efficient and, like so many systems that work efficiently in animals, biologically based. What are the implications of the fact that there appears to be no obvious invariant relationship between central commands and the effects they produce, that the order to pick up an object has wholly different consequences depending on the initial relation between the person's body and the object? This is, of course, the problem of context-conditioned variability, and it looms as large in movement as it does in perception.

To solve these problems will require, at the least, that we discover how to characterize the significant informational units of coordination and the representational structure of objects imbedded in physical space. The attempt to do the former has been a point of departure for work at the Institute for Biological Physics and the Institute for Problems of Information Transmission in the Soviet Union.[39] At those centers, investigations range from studies of the neurophysiology of motor systems, including such disorders of motor activity in humans as Parkinsonism, to the application of ideas about motor organization in the design of robots. The theoretical perspective developed in the Soviet Union has been elaborated in this country,[40] and is now being used as the basis for empirical work in several American laboratories.[41] But in seeking to understand the planning and organization of movement, and how perceptual information regulates activity, an integrated research effort is needed. Such an effort will comprise aspects of psychology, neuroscience, and computer science. There are preliminary signs that such an integration is being attempted, but much remains to be done.[42]

Strategies Governing Performance

It would seem likely that a performance strategy which is optimal for some purposes is not optimal for others. For example, in children who have accidentally lost the cortex of one hemisphere, different linguistic strategies emerge in dealing with certain grammatical constructions depending on which hemisphere was removed.[43] More recently it has been reported that with normal aging the strategies used in dealing with certain tasks change, e.g., the ways in which simple drawings are copied.[44] A question raised by these studies is whether such strategies are defective in the sense that the subjects could be trained to other strategies that would give a better performance or whether the strategies are indeed optimal when all constraints on performance are taken into account.

COMMUNICATING REPRESENTATIONS

Connections Between Phonetic Structure and Sound

As a result of years of research, we have begun to understand the nature of the code that connects the sounds of speech to the phonetic message they convey. It is a peculiarly linguistic code, bearing resemblances of a sort to the grammatical codes (e.g., syntax) that one finds at other levels of the system. More specifically, we know the code well enough to have captured it in a set of rules—a grammar, as it were—so explicit that it can be put into a computer and used for the purpose of generating speech from strings of discrete phonetic symbols.[45] The synthesized speech is not wholly satisfactory, but it is good enough to stand as evidence that this part of the problem is on its way to being solved. The rules for synthesis, when examined, suggest that the solution is not trivial. As for the technological side, synthesis-by-rule can be used—indeed, it is now being used—in a variety of applications. When connected, for example, to another set of rules, largely phonologic, that relate orthography to phonetic structures, and to an optical character reader for "perceiving" the orthography, the result may be a reading machine for the blind—that is, a machine that will convert text to speech. Synthesis-by-rule used in conjunction with other devices provides a variety of systems designed to make man-machine interactions easier and cheaper.

Higher Levels of Linguistic Representation

Linguistic comprehension and production involve the formation of multiple representations of the linguistic signal, each of which encodes some aspect of the total information conveyed by the signal. For more than twenty years, intensive research in linguistic theory has been devoted to the formal characterization of these representations and the abstract specification of the mappings among them. The phonetic representation of speech is connected to the lexical representation, consisting of a sequence of words, by means of phonological rules. Syntactic rules connect the lexical sequence to a representation of meaningful grammatical relations. Semantics and pragmatics specify mappings between this representation and a still more abstract representation of the message encoded in the linguistic signal. In computational models of linguistic comprehension and production, the linguistic rules for mapping between representations can be regarded as stored knowledge structures that are applied to decode or encode the information in the linguistic signal.

Linguistic theory has predominately been concerned with formal characterizations of the mental representations that underlie speech, and relatively little effort has been devoted to studying realistic algorithms by which these representations can be computed. Recently it has been argued that new types of syntactic representation based on the lexical encoding of grammatical relations would permit psychologically more realistic processing algorithms.[46] This and the development of advanced natural language parsing techniques[47] makes it appear feasible to construct realistic computational models of human language processing which incorporate linguistically motivated rules and representations. Collaborative work combining linguistic, computational and psychological approaches to this problem has been initiated by groups of researchers in cognitive science at a number of academic and industrial centers.

An important issue for information science arises from work of this type. A major focus of research in linguistic theory has been the discovery and characterization of constraints on grammatical structure that are invariant across languages from unrelated language-families. Referred to as "linguistic universals", these invariants are thought by many linguists to reflect specific properties of human cognitive mechanisms for language-use. Linguistic universals provide a rich source of natural constraints on the design of computational and mathematical models of natural language processing, but one that is just beginning to be exploited in the cognitive sciences.[48] A question for research in information science is what principles of information processing would explain the existence of these universal invariants in the higher levels of linguistic representation.

Understanding

There are a number of projects around the country where researchers are trying to devise computer programs that understand simple and not-so-simple stories, and where the guiding concern is the psychological reality of the representations and processes posited.[49] This work clearly constitutes an information processing account that is independent of its specific implementation, as it deals with a program that is intended to be the functional equivalent of what people do when they understand stories.

PRINCIPLES OF IMPLEMENTATION

Solutions to problems of computing and manipulating representations can be found in at least two ways: (1) by an abstract, mathematical treatment, or (2) by an empirical example. In the latter case, the nature of the illustration will depend upon the machinery available—neurons or chips, optics or computers. For example, if one wishes to represent a complex waveform as the sum of sine waves of differing frequencies, this can be done in a parallel manner using optics, or serially on a computer using a Fast Fourier Transform. Both methods give an equally informative representation of the original waveform. However, the two methods differ considerably in the algorithm used to implement the computation. Clearly, depending upon the form of the input data and the available hardware, one method will be more efficient than the other. An important example is the speech synthesis mentioned above.

With the explosive development of computer technology over the past decade, our understanding of serial processors has grown tremendously. In contrast, relatively little is known about parallel processors, such as animal and human brains. Yet these biological systems can be the most efficient information handling devices available. Understanding the computational "tricks" and strategies of the brain should provide useful insights for the construction of the artificial parallel processors of the future. Perhaps the surest way to proceed in such a "blind" search is to seek and identify general principles that appear almost universally in all biological information processing systems. These principles are revealed on at least two levels: behavioral and anatomical.

The "Magical Number Seven" is an example of a behavioral principle.[49] The average person can recall correctly a list of seven binary digits or seven decimal digits, or seven words, each chosen at random. Clearly it is the total number of items in the sequence that is the limiting factor in the span of immediate memory. This limitation has suggested that the brain will tend to encode material in such a manner that it need not handle more than seven items or "chunks" at a time. The theoretical reason for this empirical result is not known, and yet it suggests an important design principle for storage and retrieval in a hierarchically organized parallel processing system.

Two other design principles that appear both at a behavioral and an anatomical level are "lateral inhibition" and "opponent-processing". One function of lateral inhibition in neural nets is to reduce redundancy. The second is the normalization of the sensory signals over a wide input range. The scheme used to accomplish these tasks has been studied in great detail,[50] and the basic (two-dimensional) Laplacian operator is now used almost universally in image processing. "Opponent-Processing" is a related technique also very common in biological systems. It is the pairing of mutually exclusive signal types, such as "red" opposed to "green" or "black" opposed to "white". Although *why* particular pairs are chosen is not always understood, the universality of this opponent-process suggests that it may be an efficient method for handling information. Its utility can perhaps best be understood as a binary selection strategy, where inputs at each higher level of processing are successively graded by placing the results into one of two bins.

At an anatomical level, we also see the continued recurrence of certain features, which suggest underlying principles of implementation. For example, many structures of the brain are subdivided into layers (laminae) in one dimension and "slabs" or "columns" in an orthogonal direction.[51] Clearly the design of the brain cannot be random, and this type of architecture seems to be one of its organizing principles. The theory of why such a scheme is used has not yet appeared, however, and may await further developments in complexity or network theory. Other organizing strategies used by the brain include reciprocal feedback between hierarchical structures (i.e., cortico-thalamic) or laminae (as in the spinal cord), as well as temporal patterns of interaction that seem to be regulated principally by the limbic system. The latter have been likened to ring memories.

Understanding the design of the brain therefore includes not only the understanding of the problems it faces, but also the manner in which it computes solutions to these problems. By discovering the "tricks" used in common by biological systems, we advance our general understanding of how efficient, parallel information-processors could be built.

CONCLUDING REMARKS

Both the science of information and that of behavior are fast changing fields, each impacting the development of the other. It is not surprising, therefore, that what we have said about biological solutions to information handling is far from comprehensive, and we would be foolhardy to think that our sense of important topics is much of a prognosis as to what is happening right now, let alone five or ten years from now. Our purpose in trying to present the behavioral approach is to foster further interaction, not to prescribe its direction.

References and Notes

1. The purpose of this report is to suggest types of research in the behavioral and linguistic sciences that seem to have a direct bearing on the development of the science of information. We neither attempted a synthesis nor a comprehensive survey of relevant research. Our goal was more modest: to provide illustrative examples of current or recently completed research that, in our opinion, would have reasonably fallen in the domain of the Division of Information Science and Technology had it existed when the research was funded. Our list of studies is idiosyncratic; another group of comparable consultants might have cited different projects. We hope, however, that our broad categories are a good deal less idiosyncratic.
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Report of the

WORKING GROUP ON INFORMATION TECHNOLOGY

of the Advisory Committee for Information Science and Technology National Science Foundation

Introduction to the Report

The Working Group on Information Technology was convened at the request of the Advisory Committee for Information Science and Technology of the National Science Foundation under the direction of Advisory Committee members Paul A. Strassmann and Richard I. Tanaka.

The Working Group was charged with identifying research gaps related to information technology which are unlikely to be filled by the private sector but which are important to the national interest and therefore appropriate candidates for Federal action.

Similar questions have been considered by other groups and at greater length during the past several years but generally within the more limited context of particular agency or national interest problems (cf., e.g., [1, 2, 3, 6, 10, 14]). Other nations have generally adopted a more comprehensive and unified position in their consideration of analogous issues (cf. [7, 9]). It was not the task of this Working Group to reiterate the arguments of previous studies nor to undertake a detailed study itself, but rather to synthesize prevailing knowledge and expert opinion at the most comprehensive level in terms of both subject matter and its potential significance for the nation.

The members of the Working Group are all outstanding leaders in their fields and combine extensive experience in business, government, and academic life with expertise in science, technology, and industrial management. This report is the collective result of their considered opinions developed over an extended period of time rather than from their intense but brief examination of the issues in the context of the Working Group alone. Moreover, the recommendations result from the consideration of a much broader set of issues from which the issues selected were judged to have the most important national consequences and require Federal action. It should not be concluded, therefore, that issues omitted from this report are without merit.

On behalf of the Advisory Committee for Information Science and Technology, and of the National Science Foundation, we wish to express appreciation for the time and thoughtful consideration members of the Working Group brought to their task. It is our hope that the readers of this report will give serious attention to its message of opportunity and promise.

Joe B. Wyatt, Chairman
Advisory Committee for Information
Science and Technology, NSF

Howard L. Resnikoff, Director
Division of Information
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REPORT OF THE WORKING GROUP

1. Introduction. Civilization is based on the interplay between mind and muscle. Since James Watt's perfection of the steam engine 200 years ago, technology has concentrated on supplementing and replacing human muscle power by the power of energy-intensive machines. In the coming century technology will surely concentrate on supplementing and, in the more routine contexts, replacing human mental activity by the power of information-intensive machines.

There is no need to dwell upon the manifold changes in our life that information technology has already brought to pass. Telecommunications, including the telephone and television and mediated by the satellite, computers large and small, copying machines, videodisks, and other means for storing large quantities of information in an accessible form have in combination changed how and whether many of us work and play, created vast new industries and forced old ones into decline. A large and rapidly growing fraction of the American workforce derives its income from activities related to the production, communication, and transmission of information rather than from the production of material goods, and this trend will continue [9, 11, 15]. Automation of industrial production using intelligent robots, improvement of public education and workforce training by means of computer assisted instruction, growing international imports and exports of information [3], increased consumer and public access to information, and national defense are all increasingly dependent on advances in information technology, which has begun to assume the status of a national imperative. Heightened economic competition from our trading partners, the changing character of the workforce, computer crime, and problems of personal privacy are also products of the rapid changes in information technology.

This report concentrates on identifying aspects of information technology where research developments appear to be in the national interest but are unlikely to be pursued by the private sector for one reason or another. In these instances it seems appropriate that the Federal government play an active and supportive role in accelerating and coordinating the necessary developments. We have tried to set forth a general framework for decisions on Federal resource allocation which is broad enough to accommodate the rapid changes and varied implications characteristic of this new technology while still focussing on the several particular areas where we believe there are special prospects for high returns from moderate investment risks.

This Working Group is composed of engineers and scientists. Thus the reader will not be surprised to find that questions lying outside the technical sphere have generally been accorded slight attention in this report despite their evident importance. With regard to public policy issues, the forthcoming report of the National Academy of Sciences [14] complements this one. Other issues, especially those involving the societal impact of information technology, should be considered by appropriately constituted working groups.

The present time appears to be especially propitious for taking stock of the implications of information technology developments and the opportunities for the Nation inherent in them. The power of information processing machines has increased, and the costs have declined, to the point where machines which exhibit some degree of "intelligent" [i.e., decision making] behavior are spreading throughout society (cf. [12]). The convergence of computing and telecommunications technology is accelerating that dispersion. For instance, it is expected that 10 million Americans will be "on-line" by 1986, and 30 million by 1990. Thus it is not too soon to try to gain an overview of the opportunities ahead and of the gaps which may stall progress toward their realization. But it is also not yet too late for planned and coordinated activities of the private sector and the Federal government to fill those gaps.

The Working Group's recommendations call for more intense activities in eight general areas:

- Theory of Computation
- Knowledge Representation and Delivery
- Man-Machine Interface
- Software Production, Maintenance, and Obsolescence
- Very Large Databases
- Ultraparallel Hardware Designs
- Research Infrastructure
- Societal Impact

The following sections present brief descriptions of the eight general areas and identify particular problems within each one which seem to us to call for intensified effort. The discussion begins with the most general and abstract issues and proceeds to increasingly particular and practical ones. Although problems of the research infrastructure and societal implications, discussed in sections 8 and 9, lie outside the principal areas of expertise of the members of the Working Group, they are of such clear and pressing importance that we find ourselves obliged to draw attention to them, as others also have done.

2. ***Theory of Computation.*** **Computational processes lie at the root of all applications of information technology, so it is not surprising that theoretical investigations into the complexity of calculations should play a fundamental role. An early and decisive result—a triumph of pure thought—was the demonstration, about 50 years ago by the mathematician Goedel—that not every mathematical truth can be proved. This means that there are calculations which cannot be carried to completion by a computer no matter how powerful it may be. Such conclusions have profound philosophical implications but few practical consequences. They have, however, provided the incentive for recent research into the computational complexity of practical problems, and into the trade-offs between complexity and accuracy of computations for problems where some degree of error can be tolerated. The significant results which have already been obtained have immediate application to problems of data security and privacy. They have had a major influence in the area of optimization, and have greatly increased the size of problems that are routinely solved to improve the performance of various commercial, industrial, governmental, and academic operations and systems.** Further progress will play a role in stochastic computation, in parallel computation, in the design of computers, and in structuring information processing problems so that their computational requirements can be efficiently met.

Because of its long-term nature and universal characteristics, research in the theory of computation is primarily conducted by university scientists and is supported by Federal grants. While the importance of continuing research in this area appears to be generally admitted, we believe that a more intense effort will repay the relatively small investment required and that the appropriate Federal agencies should encourage activity in this area.

3. ***Knowledge Representation and Delivery.*** At the present time, only biological systems can deal with complex knowledge problems. Nevertheless, the human brain appears to function as if it were, in effect, a complex, highly parallel computer. This establishes a fundamental link between the abstract considerations of the theory of computation and the more concrete but equally fundamental research questions related to how knowledge is represented in the brain and how it might be represented in the machine. The question of immediate practical interest, of course, is how to represent knowledge in a way that the machine can usefully manipulate and that seems natural to, and can easily be used by, a person.

As the complexity and performance of microelectronic circuits increase, more powerful ways to supplement and augment human performance in areas involving programming, decision making, design and analysis of experiments, and evaluation of data become possible. Equally important is progress in increasing the efficiency of communication across the man-machine interface by using higher-level information-bearing structures such as natural languages (in both written and spoken form) and graphic representations. The effectiveness of these methods depends to a large extent on the ability to transfer knowledge and information from one representational form to another and, ultimately, to classify and recognize patterns and representations of knowledge in a way which is compatible with, if not identical to, the way the human brain performs.

Research on these fundamental questions has begun although the number of workers is still small and the goal distant and ill-defined [1, 5]. Because of its long-term and basic nature, few private-sector companies have the resources or the motivation to invest heavily in the general problem of knowledge representation, although research on selected problems with a more immediate anticipated return on investment is being done. Amongst these are information retrieval and graphic display, and the use of artificial intelligence principles to develop "expert systems" for assisting professional knowledge-workers in specific tasks which involve the analysis and evaluation of large quantities of controlled data, such as assessing the economic potential of mineral deposits from geological survey data. These applications are beginning to prove their economic value, but they must be viewed as the products of a primitive "knowledge engineering" which thus far lacks the scientific base which would enable its full potential to be realized.

An understanding of the laws which govern the representation of knowledge, whether in the brain or in the machine, requires progress on a number of basic and intricate special problems, including

- development of a general theory of pattern classification and recognition, and
- understanding the relationship between language and mental representations of knowledge, and in particular, between the structure of questions and stored knowledge.

Amongst the various sensory channels available to people for communication, the visual channel has by far the greatest capacity. This is the reason that graphic displays have become so popular in interactive man-machine communication. However, if information is communicated solely by displaying text in a natural language, then the high potential channel-capacity of the vision system is degraded so that the effective capacity is no greater than that of the speech channel. The introduction of images in addition to text, and in place of text, recaptures the advantages of the broadband vision system: those who said "one picture is worth a thousand words" knew whereof they spoke. Thus there are special research needs in the study of interactive graphic communication—especially in understanding how to substitute graphic and symbolic forms of communication for text and how graphical and image information should be organized for storage, retrieval, and display.

The Working Group believes that there is insufficient research in the broadly construed area of knowledge representation (and more broadly, artificial intelligence) and that existing efforts could be better focussed.

4. Man-Machine Interface. Dramatic improvements in the performance of computer-based systems have perhaps masked the fact that several areas have not made any basic or fundamental advances. Information machines are fast and precise and do not forget. People are slow and inaccurate and have a very limited capacity for short-term memory recall. Human information processing limitations are balanced by an exceptional ability to abstract, generalize, and synthesize. All of these are processes for reducing the channel capacity required to process information so that results can be obtained rapidly enough to be of use. These abilities also tend to reduce the significance of individual errors.

Contemporary computers cannot abstract, generalize, or synthesize to any significant degree. Thus the main problem concerning the man-machine interface is to make these two very different modes of information processing compatible; to "match the impedance" across the interface (in the engineer's jargon) in order to make it transparent and friendly, with the intent of enabling the machine to correct non-substantive operator mistakes, and otherwise forgive human errors, and to adapt itself to human thought processes rather than requiring the human user to use unnatural thought processes.

This problem is composed of a number of more specific research questions which appear to be receiving only limited attention. Since people normally communicate using spoken and written natural languages, a better understanding of how language can be used to communicate with machines is needed. It is particularly important to reduce the interface barrier for written materials in machine-readable form. Large amounts of text are now available in machine-readable form. As word processing systems become more widely adopted, the amount available as a by-product will rapidly increase. Its effective exploitation will depend on:

1. Recognition of the importance of providing standardized means for handling machine readable natural language text material;
2. Definitions of tasks and specifications for research leading to the design of general text handling systems;
3. Efficient software to perform the desired text handling functions;
4. Convenient human-factors-engineered terminals and desktop systems.

These factors lead to a number of general research topics.

Regarding the immediate future, it would be desirable to develop methods for the general retrieval of information and data items from text by word-processing systems. This could lead to widely dispersed and relatively inexpensive systems for the selective dissemination of information from locally created and maintained text collections.

In the area of the human interface, there are important research topics concerned with the evolution of existing techniques into more comfortable and natural machine systems, with emphasis on accessibility to non-specialist users and particularly on adaptive interfaces capable of becoming increasingly terse as the frequent user and the machine gain familiarity with each other. Their study would also help define the requirements for research in graphic displays, methods for storing graphic information, and internal systems useful for direct processing of graphic or pictorial data.

Some fundamental research on two-way interfaces other than the usual keyboards and cathode-ray tube displays should be encouraged to prod the development of more natural interfaces. This would include the exceptionally important natural language voice input and output systems, as well as more sophisticated tactile and visual communications means.

5. *Software Production, Maintenance, and Obsolescence.* Massive investments have been made in software prepared using "traditional" languages, and large staffs of programmers trained in them exist in commercial, industrial, and governmental organizations. Even research aimed at fundamental change in machine architecture is influenced by these facts.

For example, if highly parallel machine architectures become possible, the basic problem of providing software for such machines needs to be addressed. One approach has been to require that even machines with new and different architectures should be able to run software written in currently popular languages, instead of requiring special languages. That concept needs to be questioned. It might be more reasonable to have a combined research activity on architecture and software which attempts to keep the software problem within bounds. The software requirements could be kept within limits either by requesting that existing programming languages and programs be usable, or by minimizing the programming problem by the manner in which new machines are organized. Software languages need not be elementary. They need not be designed simply for the beginner but can be intended to be efficient and comfortable to use at all levels of skill. A software system can be interpreted in a broader sense to include database systems which use interface characteristics and some internal, sophisticated levels of processing to permit extracting knowledge or information from data.

Through the years the fraction of total information systems costs devoted to software development and maintenance has been steadily increasing. The life-cycle costs of software are not clearly understood. The basic costs involved in developing a program in the first place are known to be very high. However, perhaps 75% of the total life cost of software is devoted to maintaining and updating existing programs. This problem may be particularly extreme within the Federal government, where procurement policies tend to favor retention of obsolescent hardware and the associated software inventory [4]. Thus research is needed on the economic consequences of various procurement and standardization policies.

The question of software development and maintenance is a research area whose economic implications will become of crucial importance as the national investment in software continues to grow and the fraction of total information systems costs devoted to it climbs even more rapidly. In these circumstances, obsolescing software capital may have economic consequences quite comparable to those of obsolescing steel mills or other manufacturing capital. Productivity may in fact become negative in the long-term maintenance of aging software. It is, however, important to recognize that despite the problems noted, the United States currently has a considerable competitive advantage with respect to other countries in software development. Efforts should be made to maintain and emphasize that advantage.

6. *Very Large Databases.* The *size* of a database is its dominant characteristic. Everyone knows that a shelf filled with books or a personal filing cabinet filled with documents is a convenient store of information to which the user has immediate access. But a large library or record facility, such as the more than 20-million volume Library of Congress (equivalent to about $2x10^{13}$ bytes of information) or the record storage division of a large corporation, can be as effective as encryption in foreclosing access to desired information unless it is equipped with sophisticated data management and information retrieval systems.

As the size of the database increases (and new high density low-cost storage means such as videodisks become generally available), the problems of designing adequate retrieval and management systems increase also. If the stored information is heterogeneous, as normal office records, scientific and technical information, etc. are, these problems become still more complex. They include at least the following:

1. How to verify the consistency of updates to an existing database.
2. How to make access to a database more natural, rather than through the tightly disciplined requirements currently typical of database systems, without unduly sacrificing system performance.
3. How to configure a system and represent data so as to increase the user's ability to extract information from the data.
4. How to develop methods for quantitatively analyzing the hardware, software, and performance costs of database management and information retrieval systems as part of the design process.
5. Discovery of optimum techniques for managing distributed databases.

A key area of current database research, in which major progress can be anticipated, is that of designing storage and retrieval arrangements that can support a variety of data models perceived by users, and the related issue of the ability to translate from one pre-existing database to another.

Some other research topics related to large databases are:

- Research in computational linguistics: automating the grammatical and meaningful manipulation of natural language.
- Research on typical intellectual and commercial use of information flows: where it is obtained and how it is used.

- **Research on data structures**: the computational efficiencies of different data representations and storage and retrieval structures.

7. ***Ultraparallel Hardware Designs.*** Research topics in the area of hardware can focus on a number of reasonably obvious directions. One would be in the area of components, and of the physical phenomena underlying new methods for implementing digital hardware systems. However, it appears that the commercial sector is vigorously pursuing this direction, and the capabilities and availability of integrated circuitry are well in advance of improved system and machine architectural concepts.

One interesting approach towards exploiting the availability of large numbers of microprocessors would be to explore the fundamental properties of highly parallel machines (cf. [13]). This is a natural extrapolation of current semiconductor technology. Computing systems composed of large numbers of identical elements are ideally suited for current techniques in semiconductor processing.

One objective of a highly parallel system would be to have processing power grow more or less linearly as processing elements are added. This would require a modest number of different types of elements, each designed to carry out a specific operation with great efficiency. If one were able to provide processing power directly in proportion to the addition of easily replicated hardware units, it would be feasible to evolve a family of variable-cost information systems, ranging from low to high, with proportionate or equivalent ranges in processing capabilities.

The development of parallel computers has proceeded in an evolutionary way since the early 1960's. Current NASA plans call for construction of a highly parallel computer adapted to fluid dynamics calculations, and the Japanese government has committed itself to the development of several still more powerful parallel machines. But these proposed architectures are specifically adapted for scientific computation and are unlikely to be well suited to such other important applications as data management, computer graphics, and other complex data-intensive processes.

The ability to put together large numbers of processing elements need not be confined to parallel machine architecture. Several research studies dealing with different concepts, such as array processors, variable threshold elements, highly redundant systems or so-called adaptive logic techniques have been undertaken during the past two decades. Nevertheless, because of the availability of inexpensive microprocessing elements the current practicability of implementing many of these systems makes it feasible for some of these alternatives to be tested and compared against each other on the basis of relatively pragmatic performance criteria.

A second area in which research into machine architecture could be encouraged is in various forms of memory organization, including well-known but as yet unsolved problems involving associative memories. Such memories could of course form one intelligent subsystem, where complex storage and retrieval processing is performed in an environment separate from the host computer itself.

There are certain categories of research for which currently available equipment is not appropriate and where parallel processors may afford special opportunities for a significant advance. Highly parallel processors whose architecture is specifically tailored for modelling neural and cognitive processing may provide a revolutionary advance in experimental opportunities for investigating representations of sensory information, and in particular, of the vision system. The photosensitive receptors in the human eye have a combined channel capacity of the order of 10^{10} bits per second; the foveal cones which mediate color vision have a channel capacity of about 10^{8} bits per second. In order to simulate human vision information processing in real time (i.e., at the human rate) with a sequential computer, a machine having a cycle time of less than 10^{-10} - 10^{-11} sec. would appear to be required. The real-time requirement cannot be given up lightly, because certain applications wherein computer vision systems interact with a human operator in real time must operate at human speed. Current microcomputers have typical cycle times in the range 10^{-6} - 10^{-7} sec., which suggests that a highly parallel device consisting of 10^{4} or more microprocessors may be necessary for meaningful real time computer experiments.

Information processing performed by the central nervous system is no less complex. Realistic simulations and experiments, whose results will also lead to improved models of neurophysiological and cognitive functioning, will demand even greater computing power. And it has already been remarked that the greatest potential gains from the use of information technology will continue to come from its use to supplement human mental activities. The provision of a radically more powerful tool for investigating cognitive and neural information processing is particularly important in accelerating progress toward that goal and toward a more realistic view of the true complexity of biological systems, especially the human brain.

In this section hardware aspects of parallel processing have been discussed. The time may be ripe for taking a revolutionary rather than an evolutionary step in the direction of parallel processing instrumentation for studying cognitive information processing and other complex computing tasks by undertaking to construct a machine consisting of as many as 10,000 microprocessors appropriately interconnected. This is within the capability of current technology and is a particularly attractive possibility because computing systems that are composed of large numbers of interactive elements are the kinds for which semiconductor technology is most suitable. Thus, from a hardware point of view, it is surely the best way of maximizing the computing power per dollar. The main problems which will be encountered concern how such a machine can be programmed to perform a useful range of tasks. We therefore strongly support studies undertaken to investigate the architecture and programming problems associated with such ultraparallel processors and, should their conclusions be promising, recommend that high priority be given to their construction.

8. *Research Infrastructure.* Research advances in information technology and related fields depend on an adequate supply of properly trained researchers and the availability of modern experimental equipment. Because of the explosive development of information processing in government and industry there has been a prolonged drain of trained investigators away from university research and teaching, so that research personnel are not being trained in sufficient numbers to supply current or anticipated needs. These problems have been described in detail for computer science [6] but they extend to the related fields of information science and cognitive science also.

This Working Group supports the conclusions of [6] applied to the broader context of all of the information and engineering sciences related to information technology, and recommends that this basic problem receive the urgent and coordinated attention of the Federal government, the universities, and the private sector, with the objective of finding cooperative means for alleviating it.

9. *Societal Impact.* So much has been written about the potential impact of information technology that we can hardly hope to break new ground. Nor are we experts in the disciplines which are normally concerned with such matters. Yet the implications of information technology for our Nation—indeed, for the world—are already becoming so portentous that we find ourselves obliged at least to identify certain topics which we believe should receive the attention of specialists in the relevant areas.

Information technology already augments and partially substitutes for mental activities, so that those who know how to use this new technology and have access to it are outdistancing those who do not know or do not have access. Thus the already large gap between the highly trained and educated and the untrained and uneducated, will grow, perhaps to dangerous proportions. Moreover, industrial and governmental employment will increasingly be limited to the more highly trained and technology-literate members of the workforce [15]. For these reasons we foresee a worsening education and training problem. Information technology can, of course, also be used to alleviate these problems through machine mediated instruction and training but these methods are not yet economically viable nor generally effective apart from some specific situations. We think that all aspects of this already serious and potentially critical problem deserve the most careful analysis and attention and that, in particular, the pace of research in the use of machines for instruction and training should be quickened.

Periods of pride, economic robustness, and optimism in America have historically resulted from or coincided with very strong technological leadership. During recent years the U.S. position relative to other developed countries has diminished and our ability to employ our advantages successfully has declined. It is not too soon for the United States to evaluate the consequences of living in an information age and to attempt to improve the Nation's future in this regard. Although waning in some areas, the U.S. position of leadership in information processing and associated computer based communication is well established and our stores of valuable information remain second to none.

But the heart of a policy of sustained leadership in the development of information technology and its broad application throughout American society is a national commitment to computer literacy. Consideration of this as an objective must be coupled to a serious assessment of the key technological advances and social adjustments which must be made should the Nation choose as a matter of policy to markedly increase the number of people who know how to use computers and other information machines. Previous sections of this report have identified many of the technological developments which would have to be in place.

Many Americans are certainly feeling the strains of accommodating to the information age. It is easy to wonder at what stage personal independence will be threatened as a result of inability to acquire, process, disperse, and store the information each of us will find necessary to remain competitive and employable, and how increased access to ever increasing stores of information can be reconciled with personal needs for privacy. These issues combine problems which, if not faced, may flourish, and opportunities which, if not grasped, may move beyond our reach. They deserve timely and serious attention.

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Report of the

WORKING GROUP ON THE CURRENT STATUS OF THE INTERFACE BETWEEN INFORMATION SCIENCE AND ECONOMICS

of the Advisory Committee for Information Science and Technology
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Summary: State of the Art

The economics of information and information science have been rapidly developing fields in recent years. They are concerned, broadly speaking, with the same questions. How should information be produced, conveyed, stored, retrieved and utilized? Who should have access to what information? What are the incentives for gathering and disseminating information? What are the consequences of the unequal distribution of information in the population?

Despite this commonality of interests, and despite a common mathematical heritage rooted in probability theory and convex analysis, there has been little scientific interaction between researchers in economics and in information science. The present manuscript is a survey, by economists, of the state of research on the economics of information, emphasizing those aspects most likely to be of interest to information scientists. We also present a brief discussion of the principal areas in which there are researchable open questions that would benefit from collaborative efforts between information scientists and economists.

Summary: Research Areas for Future Study

The brief summaries that follow are intended to be representative of the topics and questions in which economists and information scientists might find common ground. The background for each is given in the main part of this manuscript. In some cases, research in these directions is already under way.

Design of Organizations as Information Processing Systems

Economic theory has concentrated on assessing the value of information and the informational needs of organizations to achieve certain goals. It has been much weaker at developing the cost side. The study of the value of information arose naturally in conjunction with parallel developments in general equilibrium theory and statistical decision theory.

The costs of information have several origins: direct costs of gathering information, costs and errors due to aggregation and quantification, costs of transmission, coding and decoding, and costs of storage and retrieval. In each case, the purely technological aspect of these costs is comparatively minor, and is decreasing rapidly as new computer-based technology is implemented.

The larger part of costs is harder to measure. It lies on the man-machine interface, or within the fabric of the organizational structure itself. It may be all too easy to produce data relevant to a decision problem. What is difficult is verifying that these data are indeed the relevant variables, that they do not need to be modified in some way, that they are actually representative of what the decision makers are assuming, and more generally, performing the computation necessary to evaluate them. One well-known problem of this nature is informational overload.

Economists do not yet have an effective class of models for these issues. Two kinds of further work are needed. First, models of information transmission and utilization in organizations with a hierarchical structure are necessary. The function of hierarchies in economic theory, thus far, has been for the higher levels to monitor the behavior of the lower levels. Their roles as processors, filters and requisitioners of information have been neglected. Because the costs of information are intimately connected with the structure within which it will be utilized, these design problems should be studied in tandem.

Second, the economic consequence, and indeed the meaning, of better information should be examined. For a single decision maker, more information is obviously better, at least until the processing and evaluation limits of the decision maker are reached. But when the decision-making unit is an organization or system with disparate parts, improved information at the source may not result in an improvement at the stage of final utilization, and local optimization of the role of information may not coincide with global optimization.

Competitive Markets as Information Processing and Dissemination Systems

It is well understood that economic agents can use the observed market variables as a source of information that they do not directly possess. This idea has had a tremendous impact upon the theory of finance, where it leads to the "efficient-markets" hypothesis, and the theory of macroeconomics, where it is imbedded in the "rational expectations" theory.

Despite the fact that both theories have been extensively developed and tested, there is a great need for further work. These theories are in the tradition of equilibrium analysis. They ask, what would be the resulting allocation of resources if everyone knew the structure of the system and was capable of making costless and error free inferences from all the observable data. The process through which the structure of the system is ascertained is ignored.

The absence of any active learning from these theories may be the source of some recently discovered empirical paradoxes. Although the average return to those holding securities seems to be well explained by the efficient-markets hypothesis, the variability of returns is not. Asset prices seem to be much too volatile relative to their underlying determinants, such as dividends. It is certainly premature to assert that this discrepancy is due to the process of learning that accompanies the market transactions, but it is an interesting avenue to pursue.

Another area of potentially fruitful research would be to examine models where the endogenous market-determined variables convey some, but not all, of the information possessed by others. The decision as to whether to acquire the information directly or to accept the less accurate but presumably cheaper mode of making inferences from market variables is an interesting aspect of this problem. It becomes an important factor in the following way: as more people engage in active information-seeking, the better, presumably, will the endogenous variables reflect underlying information. Consequently, the lower will be the incentive to acquire it directly. Is there an equilibrium fraction of traders who engage in active information acquisition in this way? Is this equilibrium efficient, or should direct information acquisition be encouraged or discouraged?

Finally, research should be directed at the role of information as a commodity. The models discussed above have retained the traditional viewpoint that information acquisition and processing take place at the level of the decision-making unit, but that information is not otherwise bought and sold. The issues of reliability, privacy and quantifiability of information are important here. These topics are related to, and logically prior to, an evaluation of the economic value-added of the information processing sector and of innovations in information technology.

Public Information Quality

Recent research in economic theory has made possible the modelling of processes such as auctions where the information available to the participants has an important influence on the outcome. Similarly, the publicly available information embedded in crop forecasts and in inventory levels for grains is an important determinant of futures market prices, and hence of the allocation of agricultural resources.

The theories currently available are highly simplified. They assume, for example, that the object being auctioned has the same ultimate value to all possible purchasers. Their conclusions about the value of improving information may be sensitive to these assumptions. Further work is needed to develop usable procedures for evaluating the impact of changing the information made publicly available, or for changing the auction rules or market-structure itself.

THE CURRENT STATUS OF THE INTERFACE BETWEEN INFORMATION SCIENCE AND ECONOMICS

1. Introduction

Acquiring and using information is a cornerstone of economic activity. In order to channel resources to their most productive ends, needs and capabilities must be identified. Incentives must be created for individuals to coordinate their activities and to willingly pool their information. Institutions, such as contract-enforcement, organizational structures and communication links, must be established and controlled in order for the system to function smoothly. All these aspects of economic behavior require information and may be impeded by its absence or its inaccuracy.

As our economy becomes increasingly complex the demands for more, better and faster information grow dramatically. The institutions in our economy are shaped by informational considerations, and conversely, induce demands for superior information processing and transmission. Economic activity and information processing are symbiotic.

For these reasons, the availability of information and the ability to evaluate it quickly, accurately, and at a reasonable cost are important goals for national economic policy. Information science and economic science are natural partners in any systematic study of the effects of informational policies or technological improvements. Their common mathematical roots make collaborative research possible, and such efforts are long overdue.

The economics of information, as an academic subject, predates the data processing revolution. In the last 15 years, however, its development has accelerated markedly. Uncertainty is pervasive in the economic environment. As economists came to recognize its effects, and the way in which it has shaped our institutions, many diverse problems have been viewed in a new light. Issues such as discrimination in employment, efficiency losses from taxation and competitive bidding for contracts—previously analyzed in rather *ad hoc* ways—have now been analyzed in a common framework. They are all consequences of informational asymmetries among individuals. The pooling of information and risks has been studied in finance and in the economics of insurance. The commonality of interests created by the formation of business firms has long been regarded as their *raison d'etre* and as their source of innovative potential. The desire to mitigate or share risks while maintaining strong economic incentives lies behind many long-term contractual relationships. This has received much recent attention under the names of "principal-agent problems" and the theory of "implicit contracts." Indeed, were there no uncertainty at all, economics and information science would both be rather dull subjects.

The growth of the economics of information and uncertainty as a unified discipline has been greatly enhanced by the interaction between mathematics, statistics, and economics. In addition to these fields, economists will benefit from intellectual contact with communications engineers, computer scientists, psychologists and others concerned with the impact of the electronics age upon our society. Likewise, we believe that many of these "information scientists" will find the economists' problems interesting and useful in their own areas as well. It is our hope that the selective survey and overview presented below will help forge a strong link between economics and infomation science.

One source of the widespread interest in the economics of information can be traced to the so-called market socialism debate of the prewar era. The issue was whether a socialist economy could attain an efficient allocation of resources through market-like mechanisms with the planning process. It might seem that, given identical technologies, these systems differ primarily in their ability to discover and disseminate information efficiently and in their potential to create incentives for individuals to implement socially desirable plans. In this context, it is therefore natural to focus attention on the questions: How do the limitations of imperfect and dispersed information, compounded with conflicting individual incentives, restrict the allocations attainable by mechanisms of this type? To what extent are they inferior to those attainable under complete information and fully centralized control? What is the best way to design the mechanisms, before learning the parameters of the economy, so as to optimize some objective function? And how stable is this type of mechanism to "environmental" change?

The second major impetus to work on the interface between information processing and economics is the predictability of economic fluctuations. This has fascinated economists and businessmen for centuries. Needless to say, fortunes can be made on the basis of superior predictions—and can be lost by erroneous ones. It is only recently, however, that the interplay between prediction and observation has been explored on a rigorous mathematical basis. These considerations have also been brought to bear on policy-relevant discussions. What information is necessary in order to stabilize the economy, or particular sectors of the economy? What is the effect of financial disclosure regulations and other privacy-related legislation? To what extent do such policies enhance or diminish the useful character of economic data collection and data processing?

Third, there are the questions of the specific effects and costs of information gathering and information dissemination on the economic activity in particular markets or sectors. Active information gathering strategies are important in auction markets, such as those for treasury bills and oil leases, as well as in more traditional markets such as those for agricultural products and currency. Issues of privacy, such as credit information or the details of corporations' financial positions are further examples of the pervasive conflict between the value of improved information and its costs. The information processing revolution has, at the same time, opened vast opportunities for the use and misuse of information, and changed the relative costs of information acquisition and evaluation, and of both of these compared with other decision-making costs.

The summary of the state of the art that follows is organized along the lines of this brief introduction. In the next section we discuss the normative issues of the design and performance of allocation and decision processes to operate in the milieu of imperfect information characteristic of actual economies. Then we will discuss the problems of prediction and the rationality of expectations. Finally we address some concrete models of the interaction of economic agents in uncertain environments. Particular attention will be focused on the effects of improving their private information about the state of the system. Along the way we hope to point out some areas lying close to the interface between economics and information science where interaction across these disciplines may be particularly fruitful.

2. Economic Organization and Information Science

Economic systems have many close parallels with information processing systems. Both can be shaped by conscious design to function in environments whose general characteristics are known, but whose details vary from one instance to another. For example, inventory control systems are based on the idea that sales follow a stochastic process with known parameters. At any moment, the state of the system determines its responses: adjust production, order supplies, etc. In general information processing, the nature of the data and the use to which it will be put is important in system design. The tradeoff between flexibility (i.e., universality of processing algorithms) and efficiency is central to the design both of economic systems and information processing systems.

There are, however, several important special features of the design problem in economics. Economic systems must deal with the diversity of interests of their members, as well as with the problems of imperfect information. These two facets of the problem interact, each hampering the solution of the other. Were information perfect and communication costless, conflicts of interest could be resolved by a system of enforceable contracts. Conversely, if all individuals shared common goals, the problems of choosing optimal actions under incomplete information would amount to a certain type of constrained optimization. The confluence of these two problems is often absent in pure information processing situations, and in this case one can consider the information processing problem as a kind of generalized information retrieval. In many applications, however, such as systems designed for accounting and financial control, and the so-called "expert systems," the "economic" aspects of the problem give rise to both the issues of diverse objectives and dispersed information.

The compounding of incentives-related difficulties with the purely informational problems makes it best to proceed in a step-by-step fashion in presenting a summary of related research. We will deal first with the informational issues, assuming the members of the system agree about objectives. Then, issues of divergent payoffs will be addressed, but still retaining the hypothesis that the communication process can be prescribed. Finally we allow for both conflicts of interest and strategic behavior in the transmission of information.

The costs of acquiring and processing information, in contrast to its benefits and effects, is much less well understood by economists. Part of the problem is that we do not have good theoretical models of the economic utilization of discretized information, or information (such as cross-referenced indexes) that is not easily quantified. Much further work needs to be done in this area.

A. Designing Organizations in the Absence of Conflicting Objectives: Team Theory

The theory of teams was developed by J. Marschak and R. Radner[1] (1972) in the early 1950's. A team is an organization with a well-specified objective, shared by all members, in which actions and information are necessarily decentralized. Each member is responsible for some component of the team action, and each has access to possibly different initial information. Communication can improve the payoff, but by hypothesis, channels for such communication are costly. The central goal of team theory was to compare different communication designs. Which systems achieve a high expected payoff for a given informational effort?

The theory stopped short of this goal. It proved too difficult to develop useful measures of "informational effort." Instead attention focused on the optimal utilization of some fixed information structure. Team theory characterized the best team decision rule for a given information structure. The signals which a member observes in a given information structure may be obtained through messages received from others or through direct observation. The rule specifies what action is to be taken given these observations.

The principal results of team theory deal with several special cases. When the payoff function of the team is quadratic in the actions of its members, and when the unknown parameters of this function are jointly normally distributed with some observable variables, an explicit solution can be obtained. The action taken by each member is a linear function of his observations and of the observations of others that are transmitted to him. This linear-quadratic structure is reminiscent of results in stochastic control theory, the corresponding single-person decision problem. Another special case, of significant economic importance, is the problem of the centralized allocation of a fixed quantity of a scarce resource among the members of the team combined with "local" inputs whose utilization is determined separately by each team member.[*] The principal issue in this problem is that the "local" decisions are not perfectly coordinated because each team member lacks full knowledge of the random parameters relevant to the others. The loss due to this informational incompleteness has been analyzed. It has been shown that it falls as the number of team members increases. Essentially, the team's optimal decision rules can rely on the law of large numbers to reduce the impact of uncertainty.

B. Designing Organizations in the Presence of Conflicting Objectives but Non-Strategic Behavior

The study of market-oriented mechanisms for allocating resources uses the same methodology as team theory. It is based largely on the hypothesis that consumption is private and therefore that scarce resources must be allocated among competitive uses. This has been stimulated by the economists' traditional preoccupation with the workings and the claimed optimality of an idealized version of a price-guided market-oriented economy. By 1950, due to the work of A. P. Lerner[2] (1937) (1946), O. Lange 1942[3], K. J. Arrow (1951a)[4] and T. C. Koopmans (1951) (1957)[5], economists had been able to show under what assumptions concerning the economic environment perfectly competitive equilibria are optimal and every optimal allocation is achievable as an equilibrium of the economy with a suitably chosen income distribution. The interest in such results was due in part to the belief in certain desirable informational characteristics of the competitive mechanism. It seems highly decentralized in that each individual or firm need only know its own economic characteristics plus the market prices. In this way it seems superior to the more highly centralized procedures of a "planned" or "command" economy.

To approach such questions it was necessary to formalize the informational aspects of the market mechanisms, particularly the meaning of decentralization. A rigorous concept of an abstract economic organization, or mechanism, was introduced by Hurwicz. The perfectly competitive structure is one special case of a mechanism, but there are many others.

The Hurwicz framework modeled the process of resource allocation as a system of difference equations describing the communication among the individuals in the economy. Formally, a mechanism is a triple consisting of the message space, the response rules, and the outcome rule.

The message space represents the language in terms of which agents communicate. A given agent's response specifies the message this agent will emit given the messages previously received and given his information about the economic environment. Finally, the outcome rule specifies the resource allocation (or allocations) that will prevail once the dynamic process of message transmittal has reached a stationary value.

With this formulation of a class of economic mechanisms it became possible to define various aspects of its performance. "Non-wastefulness" described mechanisms for which all outcomes generated by stationary messages were necessarily optimal. The informational decentralization property, called "privacy-preserving" specified that a given agent's response function is independent of other agents' characteristics, i.e., to determine the next message to be emitted, the agent only needs to know his/her own characteristics but not those of other agents. In this formalization, the perfectly competitive mechanism is both "non-wasteful" and "privacy-preserving."

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[*] This is, in essence, the problem faced in the distribution of central computing power to time-shared terminals. At a higher level, it is also reflected in the architecture of the computer's central processing unit, and in the design of telecommunications systems.

This framework has been widely used to formulate questions concerning the theoretical limits to performance of mechanisms having various informational properties. For example, are there mechanisms other than the perfectly competitive one that share its non-wasteful and privacy-preserving features but which require smaller message spaces? Are there others that use a space of the same size but can achieve different results?

The answers to characterization questions like these depend on the domain of economic environments over which the mechanism is to be applied. The specification of this domain amounts to the planner's admission of the range of his *a priori* ignorance of the data of economy. To date, economic theory has handled this issue in a rather non-parametric fashion. Domains of economics are specified by giving qualitative properties of agent's characteristics, such as convexity or differentiability of their utility functions, rather than by placing quantitative bounds on attributes such as endowments or demand elasticities. Insofar as the theory has achieved the result that an optimal resource allocation is achievable, that is that the limitations on communication do not in fact lead to an inferior realization, this non-parametric approach has been successful. Future research, where a greater degree of ignorance by the designer is recognized, may benefit from an alternative methodology.

The parallel between systems design and this branch of economic theory is that of the specification of the performance function to be implemented. The economic planner can be thought to describe the outcome to be achieved for every environment in some domain. In this framework, Hurwicz, Reiter and Saari have given a constructive mathematical method to find the adjustment process of minimal dimension which realizes this performance.

C. Designing Processes to Implement Social Objectives in the Presence of Strategic Behavior

The previous section dealt with resource allocation in the presence of differing evaluation of outcomes by the economic agents. But though their goals were in partial conflict they were not assumed to distort their private information so as to manipulate the mechanism to their own advantage. Honest behavior was assumed. In this section we consider some of the recent attempts to design mechanisms that achieve good outcomes, even in the presence of such strategic behavior. As a simplifying, and extreme, benchmark we will assume that individuals take full advantage of their ability to control the outcome by strategic play. Honesty for its own sake, or morality, is assumed to play no role.

With any mechanism in place, the economic system is converted in the formal sense into a game. Strategies of an agent are his responses to the mechanism and his transmission of private information to other individuals. We are interested in the equilibria of these games. Different mechanisms will have different equilibria.

The choice among mechanisms is complicated by the possibility of multiple equilibria common throughout all of game theory. The strongest kind of solution is an equilibrium in dominant strategies—when each player has a best action independent of all others. In general, mechanisms cannot be designed to achieve optimal outcomes and have dominant strategy equilibria.

If one gives up on the ideal of implementing outcomes in dominant strategies, much more can be achieved with somewhat weaker solution concepts. In the case of finitely many alternatives, it has been shown that any desirable outcome can be implemented as the Nash equilibrium of a game constructed by the mechanism's designer, if he is free to choose suitable large and complex strategy spaces. With constraints on the complexity of strategy spaces only, somewhat weaker results are possible.

D. A Reassessment of the Treatment of Informational Costs in Resource Allocation Mechanisms from the Point of View of Information Science

As path-breaking as the models discussed in the last several sections are, there are still three distinct ways in which they oversimplify the assessment of organizational costs. (1) They treat a price-mechanism for an economy as, in effect, a "one-step" design, in which observations are made, messages are announced (prices and proposed trades), and then—*if* those messages characterize a competitive equilibrium for the economy—actions (trades, productions, consumptions) take place. One suppresses the many steps which in fact might be needed to attain an equilibrium. (2) Only one information cost—that of message transmission—has been considered and it has been given one principal measure, namely dimension of the message space. (3) The price mechanism is compared (with regard to message-space dimension) *only* with designs that achieve exactly what the price mechanism achieves, namely an optimal resource allocation for each environment. The work so far completed does not permit the trading of benefits against costs. Little work has been done on ***approximations*** to the price mechanism, even though such approximations are clearly required in practice. We do not yet know the informational costs of a design which ***approximates*** the price mechanism to a given precision, with the approximate mechanism's actions falling short of the optimal resource allocation achieved by the "true" price mechanism. If those costs were devoted instead to other designs, would all such alternative and equally costly designs achieve a lower (or at least not higher) benefit than the given approximate price mechanism?

One approach is to discretize the space of decisions and messages, rather than assuming each to be a continuum as in the work cited thus far. In that case decision errors are unavoidable and instead of requiring optimality one seeks privacy-preserving mechanisms which achieve the lowest error permitted by the given discrete spaces.

All of the models discussed above neglect the computational sophistication required of the individual agents in an organization. Limited abilities and costly or error ridden computations are nonetheless important in practical design problems. One can sometimes lower the dimensionality of message spaces by requiring more complex response rules. It is thus important to be able to compare processes in terms of computational complexity, as well as on their other characteristics. Conversely, an increase in dimensionality can reduce the error rate, as for example in computers carrying "check digits."

There is a large literature in computer science and mathematics dealing with complexity of computations. At present, economists have not made use of this theory in the context of allocation mechanisms, although it seems relevant at an intuitive level. Perhaps the problem is that in some aspects this theory is too "fine," calling for more detailed information than is available, while in other aspects it is too "coarse," admitting too few kinds of computational problems. What is needed is an approach which uses the type of information available in allocation models, e.g. environmental parameters, performance functions and message correspondences, and permits analysis showing relationships between computational complexity and other informational costs or constraints.

Futia[6] has studied complexity of decision rules in an economic setting using the algebraic theory of sequential machines particularly the Kron-Rhodes Theorem. Mount and Reiter[7] have used an approach combining the "neural network" model of McCullough and Pitts[8] with an explicit formulation of the computational task associated with a privacy preserving allocation mechanism. Via an example they show that enlarging the message space permits a reduction in computational "cost," while preserving performance.

In addition to computing costs, other informational costs confront the designer of organizations, and there are a number of possible approaches to measuring them. One may break the operation of a design into the *tasks* of observing, message-sending, computing, action-taking, or possibly storage and retrieval required of the organization's members. Different approaches to cost measurement correspond to different views of the *technology* of each task. Individual theories, which characterize the technology of certain of these tasks exist but none has been developed as part of a unified effort to compare the costs and benefits of designs.

A task can be viewed as the assigning of an output (a message, an action a computational result) from a set of possible outputs, to an input (a message, an observation) obtained from a set of possible inputs. Models of the technology of such a task may be loosely divided into three families:

(i) Deterministic investment-cost-only models, wherein a device to perform the task is acquired once-and-for-all; the device stands ready to deal with all of the task's possible inputs. There is no separate charge for each successive output-to-input assignment and the probability distribution of inputs plays no role.

(ii) Frequency-exploiting investment cost-only models. Here there is again no separate charge for each output-to-input assignment, but the device used takes advantage of the fact that some inputs occur more frequently than others.

(iii) Models in which a different cost is incurred for each input-output pair, and is assessed when that pair occurs.

For the case of a computing task, the models of finite-state machine theory are of the first type. For the case of a message-sending task, the models studied in the earlier Shannon theory are of the second type. Codes are used to exploit frequency differences and to economize on channel size, as measured in symbols per time unit; and it is channel size, a once-and-for-all fixed investment, which determines the task's costs.

Much current research in computer science fits into the general framework just discussed. A computer, or a computer network, may be modelled as an organization, whose "members" include terminals, compilers, memory units, and arithmetic units. Designing software which permits the given installation to compute certain functions while providing a good balance between performance (accuracy) and cost (time) is a problem of efficient design in the sense just described. Research on various topics which appear under the labels "parallel processing," "distributed systems" and "resource-bounded computation" appear closely related to the economists' organization design problem. On the other hand, to solve a resource-allocation problem by means of a price mechanism may formally be viewed as the use of a parallel algorithm, with individual agents playing the role of simultaneously functioning processors. Research in which there is a dialogue, if not active collaboration, between computer scientists and economists concerned with informationally efficient resource-allocating designs has never been attempted. It may be an effort whose time has come.

Some current work in transmission and coding theory has gone well beyond the economically unmotivated results of the early Shannon theory. In studying a sender, who observes a source of repeated signals and is to inform a receiver about them, specific attention is now paid to what economists would call an "efficient surface." This is a surface in a space whose dimensions include channel size (in symbols per time unit), size of the block of messages which accumulates before coding and transmission, and expected value of a "fidelity" criterion. The fidelity criterion is some function of the source signal and of the receiver's inference about the signal, a function more general than the simple "error" of the early Shannon theory. Again, however, collaboration between "information theorists" (as they still tend to be called) and economists interested in resource-allocating designs is lacking.

With regard to the task of observing, it might turn out that certain work in the field of pattern recognition is suggestive for the efficient-design problem. Dialogue and collaborative efforts might well be explored.[9]

Technological advances during the past twenty years have dramatically reduced information processing costs. This has naturally led to the birth and rapid growth of entirely new branches of the computer manufacturing and software industries. The economic consequences of this revolution in information technology go far beyond those related to industrial growth. Information can now be collected, analyzed, and disseminated in such large quantities and with such speed as to substantially alter the decision-making processes of consumers and producers. Economic choices can now be made after a careful consideration of far more alternatives and with far more attention to future economic events than has ever before been possible. Will this dramatic increase in information processing capacity change the behavior of producers and consumers in ways which will irreversibly alter the performance of the market system? Can the fruits of the information revolution be utilized to improve the allocation of resources within our economy?

3. Prediction and Information Transmission through Competitive Markets Forecasting in Self-Affecting Systems

Economic forecasts are made to be used, and decisions based on them can affect the predicted events. Forecasts can be self-fulfilling as in the case of a predicted stock price increase, or self-defeating as in the case of a predicted energy shortage which leads to increased conservation and the development of alternative energy sources. This problem was originally thought to be a major impediment to the development of predictive economic models.[10] However, over the past two decades many econometricians have resolved this difficulty by including the responses of rational statistical decision makers in "rational expectations" econometric models.

More recent research has unearthed a new and somewhat deeper conceptual problem involving the relation between the beliefs of economic decision makers and the extent to which their decisions reveal the fundamental variables of the economy. A change in economic conditions may affect a decision unit's set of feasible alternatives and also the desirability of alternatives within that set. As most economic data are price and quantity data generated by market transactions, they reveal the underlying structure only imperfectly. Forecasts influence transactions and these observations. In this way they influence the knowledge on which successive forecasts will be based.

These interactions between learning and the system being learned lead to a rather different view of empirical inference than is appropriate in other fields of scientific inquiry. This is not to suggest that empirical inference in economics is inherently limited or that a new theory of statistical prediction must be invented for economics. Recent research has concentrated on identifying those economic information structures which are consistent with conventional methods of inference.

B. Information Flows and Their Sufficiency

There is a classical doctrine in the theory of competition which holds that in a market economy prices alone provide decision makers with all the information about the rest of the economy needed to reach optimal decisions.[11] This doctrine does not envisage the interaction between knowledge and observation, and many researchers have found in the latter problem a deeper application and stronger test of the classical doctrine than was previously possible. A major initial finding has been that the classical doctrine is essentially correct provided that the existing range of financial markets is complete.[12] "Completeness" here means that the set of investment opportunities should be sufficiently diverse so that full insurance against economic risks is possible. For example, a faculty member of a state university should be able to insure his future income by investing in a portfolio whose return is exactly inversely correlated with the tax revenues of the state. Under this condition prices alone transmit all decision-relevant information, although as we have stressed above, prices reveal little of the underlying fundamental variables.

While existence of a complete range of financial markets is an ideal not met in practice, it is plausible that prices disseminate much of the relevant information. On this point, however, substantial theoretical problems have arisen with the equilibrium concept itself. Indeed, it appears conceptually possible that with incomplete markets the interaction between knowledge and observation may disrupt any systematic method of inference from prices.[13] The question is still far from settled and research in this area is quite active.[14]

The actual construction of economic forecasts, when it is known that these forecasts influence the behavior of the system itself, poses a new set of questions. The preliminary results suggest that conventional methods of statistical estimation may still be applicable, although the small sample behavior of the estimates will differ substantially from that described in the theory of statistics. This area represents a potentially fertile ground for collaboration between economists, statisticians, and information scientists.

C. Policy Applications of Information-based Economic Models

One of the most important applications of rational expectations models has been to examine the role of the economy's information structure in generating business cycle fluctuations. Do emerging technologies permit changes in the information structure of sufficient scope to smooth business cycle fluctuations? A convincing answer to this question will require research along a number of barely explored avenues. We will now sketch the current state of our understanding of the connections between business cycles and information and, along the way, point out several important research problems.

A puzzling feature of business cycle fluctuations is the observed negative correlation between the rate of inflation and the rate of unemployment which is depicted by the so-called Phillips[15] curve (1958). During the 1950's and

1960's many economists believed that this correlation reflected a stable "tradeoff" which policy makers could exploit to achieve an inflation-fueled prosperity. But in one of the most influential papers published in macroeconomic theory during the past twenty years R. E. Lucas (1972)[16] demonstrated that this tradeoff was likely to be more illusion than fact. His explanation is based on the imperfect ability of economic agents to identify the component of price changes that is "real," rather than of purely monetary origin. The presence of this signal extraction problem causes the equilibria to exhibit the Phillips curve relation, but it cannot be exploited by a systematic policy.

Some economists dismiss the idea that economic agents can be so ill-informed about current and future relative prices as to generate output fluctuations of the magnitudes typically observed in the last several decades. They point out that information technologies have reached the stage where "complete" information is an attainable goal. If producers and consumers choose not to employ these technologies then it must be that the private benefits do not justify the costs; thus business cycle fluctuations do not imply an inefficient allocation of resources.

This objection is open to the criticism that it ignores a potentially serious problem of information externalities. If the decision to acquire more information indeed results in more "stable" equilibrium time series, reflecting only real rather than monetary factors, then all economic agents will benefit from the resulting reduction in uncertainty. However, these external benefits do not enter into the cost-benefit calculus of individual agents. Underinvestment in information may well result.

To determine whether this is a serious problem will require the development of macroeconomic models in which the decision to acquire information is endogenously determined. Some progress along these lines has already been made. But the appropriate analysis of economic welfare gains or losses requires business cycle models based more closely upon the maximizing behavior of risk averse economic agents.

There is another related issue which is also poorly understood. The emerging theories of the business cycle stimulated by Lucas' paper all rely upon divergences among economic agents' forecasts to generate business fluctuations. That such divergences exist is easy to document, especially in the financial and commodity markets and also among macroeconomic forecasters. Yet in all these cases it is difficult to attribute the divergences in expectations primarily to differences in the information available to different agents. Indeed, all macroeconomic forecasters have access to virtually the same set of publicly available data. Yet from this data set they infer different (sometimes radically different) models of the economy.

It is probably the case that this diversity in forecasting models is the principal source of the divergent expectations held by economic agents. If policy actions designed to alter information structures and thus affect business cycle fluctuations are to achieve their goals, they must somehow also reduce the diversity observed in the economic forecasting models. To determine whether this is likely to happen it is necessary to have a theory of model formulation and evaluation in which information availability plays a central role. This theory should predict the conditions under which model diversity can be expected to increase, persist or be reduced. Such a theory should, for example, provide guidance on the effects of a significant change in information availability. Will the added information stimulate model-builders to explore entirely new possibilities, thus increasing model diversity, or will it instead permit decisive tests of competing models, thus reducing diversity?

D. *Information and Behavior under Uncertainty*

The economic model developed by Lucas (op. cit., 1972) is one of general economic equilibrium under uncertainty. But despite its structural simplicity Lucas was unable to determine whether or not there was some monetary policy rule which could offset the information deficiencies and thus reduce or eliminate the model's output fluctuations. For in order to answer this sort of question one generally must be able to derive explicit expressions for the stochastic equilibrium time series. This is not usually possible if there are any significant non-linearities present in the model's structure.

The obvious solution to this difficulty is to forego the analysis of models based upon the utility maximizing behavior of risk averse agents and instead work within a linear, certainty-equivalence, framework in which risk preferences play no role. The first major example of this approach in the macroeconomic literature appeared in a controversial paper by Sargent and Wallace (1975).[17] It develops a linear macroeconomic model which incorporates Lucas' supply hypothesis, i.e. that output fluctuations occur only when price fluctuations are misperceived as arising from real demand shifts. Sargent and Wallace demonstrated that any monetary policy rule which permits economic agents to anticipate the future changes in the money supply will have absolutely no effect upon real variables.

This is a remarkable result. However, it has widely been misinterpreted as indicating that the hypothesis of rational expectations precludes monetary or fiscal policies from having effects upon real variables. But in fact the Sargent-Wallace result arises solely from the specific information structure they assumed. This point was made by Weiss (1980)[18] who demonstrated that under an altered information structure monetary policy can be effective. In fact, he exhibited a policy based only upon publicly available information which alleviated informational deficiencies structural to the economic system.

The literature cited thus far contains many new insights into the role played by information and communication in macroeconomic fluctuations. Yet this "linear models" literature has a serious weakness. Its behavioral relationships are based upon the certainty equivalency hypothesis which asserts that only the expected values of random variables (but not their riskiness) affect economic decisions. This hypothesis should cause one to be skeptical of the conclusions these models reach about the possibility of smoothing output fluctuations through systematic monetary or fiscal policies. For such policies will affect the riskiness inherent in the economy's equilibrium time series. This in turn will change the apparent elasticity of economic agents' responses to changes in the expected values of the random variables they forecast. In other words,the demand elasticities of risk averse agents are actually endogenously determined by the riskiness of the equilibrium time series. in contrast a linear model assumes that these elasticities are exogenously given and fixed.

In (1980) Futia[19] offers a critique of the certainty equivalence hypothesis and shows that it can be seriously misleading. The ranking of the variance of the equilibrium time series associated with two distinct information policies is reversed as soon as one introduces elementary considerations of risk aversion into an otherwise linear model. This underlines the need to study the properties of "almost linear" macroeconomic models which incorporate the implications of risk averse behavior so that we can begin to understand the possible consequences of macroeconomic stabilization policies.

E. Information as a Commodity

Given the importance of the information processing industry in the modern economy, it is surprising that there is virtually no work in the economics of information as a commodity. Part of the reason for this gap is that to value information one must know what decision problem is being faced. Without this, the demand for information cannot be determined. But as the previous sections have shown, any available information is likely to "leak out" via the price formation process. Equilibrium theories in economics (which are all we have at present), by definition, cannot capture the advantage possessed by the original recipient of knowledge over those who learn only indirectly.

As for the supply side, a few facts are obvious, but their implications are hard to follow up. Information is thought to be costly to discover but relatively cheap to duplicate in transmission. It is the quintessential decreasing cost industry. But if proprietary information is valuable only insofar as few people have it, the supplier should try to convince his buyers that only a limited number of others will receive it. However, although this may be possible at the first stage, it becomes increasingly difficult to insure that the buyers do not, in turn, duplicate and sell it.

Other aspects of information as a commodity are equally fascinating but even harder to model in economic terms. Nevertheless our discussion would be incomplete without them.

Privacy, the lack of certain information or access to it, is costly to misuse and is certainly desired by many people. In the computerized world it is often easy to access personal and financial information simply by obtaining a few identification numbers. It would be interesting to estimate the value of privacy and the costs of providing it.

Much of our discussion of information concerns the occurrence or non-occurrence of exogenous events. Yet much of the output of the information processing industry is actually a condensation of information. Data in its raw form is often unwieldy and not useful. Computers have made it possible to access particular pieces of data or to extract summary statistics that make the data more useful. Formally speaking, these are less informative than all the data rather than more informative. Data compression or extraction is economically valuable because the costs of computation and analysis are real costs.

Finally, much of what one considers important in the assessment of information as a commodity is hard to cast in the mold of decision theory at all. The purchaser does not have a clear idea of the space in which the events in question lie. Rather, what he is buying represents a mold in which further questions can be asked, or it calls the buyer's attention to a perhaps overlooked aspect of his decision problem, or to an error he has made. Just because these issues lie outside the usual bounds of information science and economics does not mean that fruitful insights could not be obtained if investigators were to direct their attention to them.

In conclusion, the relation between the expectations of decision makers and the information carried by economic data has forced a fundamental reconsideration of empirical inference in economics. Most economic data are price and quantity data which are generated not for the purpose of scientific observation but to guide the allocation of resources. Emerging results indicate that forecasting may be logically impossible unless the observed data constitute a complete set of allocation signals. The state of the research in this area leaves many tantalizing open questions on both the theoretical and empirical planes.

4. The Value of Improving Public and Private Information

A. The Effects of Changing Information Quality

The preceding sections of this essay have all taken the structure of exogenous information as given, and have traced its effects on the economic system. In this section we discuss the effects of improving the quality of information available. Such improvements can take the form of more accurate observations, more rapid communication or calculations, or new sources of knowledge.

In single-person statistical decision theory the concept of "more informative" is defined as a way of comparing information structures. It is due to Blackwell[20] (1951) and Bohnenblust, Shapley and Sherman (1949).[21] Information structure A is said to be more informative than information structure B if, for any decision problem, the decision-maker would prefer having access to A rather than B. This relationship is a partial ordering; for many pairs (A,B) one's choice would depend on the problem at hand.

In economic problems, or in multi-player decision problems more generally, there is an additional complication to consider. The players have (partially) conflicting goals. Their behavior is not perfectly coordinated. Changing the information structure may lead to new problems of coordination, or new adverse incentives. Effectively, the decision problem faced by the system, viewed as a whole, may have shifted. One cannot separate the information structure from the problem to be solved, as in the one player case.

Because of this difficulty it is impossible to find definitive rankings among information structures in general multiperson situations. Examples in which complete ignorance dominates an informative observation are known. Therefore, the research avenue that has been pursued is to narrow the class of problems over which one requires the dominance of one information structure over another. For example, players' payoff functions may be assumed to belong to a simple parametric class. Alternatively, their payoffs are identical but their prior probabilistic beliefs may be different.

In summary, a partial ordering of information structures can be defined in multi-player settings. One information structure is said to be more informative than another if, for the class of problems at hand, the model predicts a higher expected payoff when the former structure is operative.

This type of analysis has been conducted in three distinct kinds of models: market models with a large number of traders, auction models, where the number of potential bidders is common knowledge, and two person games. In each case the goal has been to find classes of models for which, when information improves in the sense of single-person decision theory, it improves payoff values in the situation being studied as well. The remainder of this section addresses these three kinds of models.

A tremendous explosion in the processing of information relevant to market transactions has taken place in recent years. Complex interrelated markets for options on common stocks have grown dramatically. Futures markets in securities and in foreign exchange have multiplied the possibilities for hedging and speculation.

Markets with similar characteristics have been a topic of interest to economists for many years. The earliest theoretical work is due to Hirshleifer (1971)[22] who showed that information commonly available before the futures markets reach equilibrium may be detrimental to overall welfare. Marshall (1974)[23] carried this line of research somewhat further. Green (1981)[24] studied futures markets which reopen repeatedly during a period of time in which new information is continually arriving. Here, in the early rounds of trading, hedging positions may offset some of the risks of price fluctuation. Green gave a set of conditions sufficient for better information to be beneficial to all hedgers. (Speculators, assumed to be risk neutral, are unaffected.)

High resolution photography in earth satellites has greatly improved the quality of crop forecasting information especially outside the U.S. The international aspects of grain trading make such knowledge directly relevant to domestic producers and users. In an interesting series of papers, Bradford and Kelejian (1977)[25] have studied the effects of these improvements on the inventory of wheat. They have estimated the benefits in both the saving of inventory costs and in the economic value of somewhat less variable spot market prices. The Bradford-Kelejian analysis does not incorporate an explicit role for futures markets, nor is it a "world-wide" model as only U.S. production is included. Extending their work in these directions would be interesting theoretically and of potentially great practical importance.

B. Information Processing in Auctions

Examining the value of information available to participants in an auction is another area where recent research has proved very fruitful. Because the rules governing most auctions are reasonably simple and well-specified and because the outcome of an auction depends crucially on the private opinions of the bidders about the objects being sold, the role of information in auctions is an interesting and tractable topic for study. To illustrate some of the issues that arise, let us consider a sealed-bid-tender auction for drilling rights on some oil-bearing property. The value of these rights depends on the amount of oil present, its cost of recovery, its quality, future prices for refined petroleum products, etc. Each of these factors is known only imperfectly by the bidders.

To a first approximation, the value of these rights to the various bidders can be regarded as equal, but the bidders are likely to have differing estimates of this value. Other things being equal, the bidder whose estimate is greatest will tender the highest bid. Consequently, even if all bidders make unbiased estimates, the winner will find that he had overestimated (on average) the value of the rights he has won. Petroleum engineers have claimed that this phenomenon, known as the ***winner's curse***, is responsible for the low profits earned by oil companies on offshore tracts in the 1960's.

There are, however, countermeasures available to a bidder to ameliorate the winner's curse. First, as Wilson (1977)[26] noted, the bidder can base his bid both on his actual information and on the hypothesis that others have less encouraging information. Second, he can gather additional information to reduce the error in his estimates.

Milgrom and Weber (1981)[27] have found it useful to divide the effects of new private information into three categories. First, the information may improve the bidder's value estimate. Second, it may improve his estimate of his competitor's likely bids. Both of these effects are unequivocally beneficial to him. Third is the "competitive effect": if other bidders know that one bidder has gathered information, they may revise their bidding strategies. Relatively well-informed competitors respond by bidding more aggressively and relatively poorly-informed bidders become more cautious—the balance depends on the mix of these bidders.

The effects of public information on the outcome of an auction has also been studied by Milgrom and Weber (1980, 1981).[28] Such effects arise when the government conducts geological tests on a potential oil-bearing site and publicizes the test results. In a general model of auctions, it is shown that for three common auction mechanisms, publicizing information raises average prices.

There is much that remains to be done in auction theory. Even in the simplest auction settings, the value of information to a bidder and the effects of public information are not fully understood. Moreover, most existing analyses ignore the fact that information is used not only for preparing bids but also for making drilling decisions. As a result of that fact, secret information in the hands of losing bidders may be wasted from the public point of view. The effects of private information gathering on public welfare are in need of study.

Nearly all existing formal models of auctions focus on the case where a single object is offered for sale. In auctions for mineral rights on federally owned properties, a typical auction involves the simultaneous sale of perhaps 150 tracts. The nature of optimal bidding strategies in that setting is still not understood. Such an understanding is, of course, a prerequisite to understanding the effects that information, public and private, has on bidding behavior.

A related set of questions concerns how an oilfield is optimally explored when competitors may own the rights on adjacent fields. In this setting, one firm's exploration expenditures can directly benefit a competitor. Consequently in the auction for these properties, a firm may choose to place high bids on several adjacent tracts to get full value from its exploration activities or it may choose to place scattered high bids, in an attempt to benefit from the exploration done by others.

Another kind of auction of great practical significance occurs daily on our large securities exchanges, where buyers and sellers make offers and bids and trade securities. It is widely believed that privately held information somehow comes to be reflected in securities prices. It seems likely that a detailed model of this process would be helpful in revising the trading rules of the securities exchanges, rewriting disclosure laws, understanding the effects of insider trading, studying corporate financial structure decisions, and analyzing how well the market performs its function of funneling capital to its most productive uses.

C. *The Value of Information in Games*

Finally we come to the question of the value of information in two-person games. The games most widely studied arise in what is known as principal-agent problems. An individual facing a statistical decision problem, the principal, delegates the choice of his action to a better-informed player, the agent. The agent does not have the same payoff. One possible way to improve the result is for the principal to limit the action to a certain subset of possibilities.

In this context, Green and Stokey (1980a,b)[29], [30] have shown that if the informational improvement is the reduction in the probability of a totally uninformative observation, and an equiproportionate increase in the probabilities of all other observations, then the principal's welfare necessarily improves. For the agent, no informational improvement can guarantee a welfare increase, even if the two players have identical payoffs and differ only in their prior probabilistic beliefs.

Crawford and Sobel (1981)[31] have asked the converse question: When does a more similar pair of objective functions induce a higher degree of fidelity in the equilibrium transmission of information?

This line of research is obviously in only its formative stages. The hope is that one can develop a theory of the potential welfare effects of improved information to players in a game and, in this way, discover whether the appropriate incentives for information gathering and dissemination exist. If a player might lose from acquiring more information, he cannot be expected to invest in such acquisition. Prospectively, therefore, the organization of communication and control might be so arranged as to provide the right incentives, from the group's point of view, to the members whose access to new information would be of the greatest value.

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Mr. **Walgren**. Thank you very much, gentlemen, for all three of those statements and your contribution to the support for this area. We have been sort of focused on this 1980 year level of funding. That, too, is arbitrary in every way, I am sure. It has a political mark to it that should, I think, find broad support on both sides of the aisle. Yet I couldn't help but note Dr. Juster's comment that you really have to ask kind of a different question as to the level of funding. The question, I guess, is what do you not do and how do you measure that against what you don't do in other disciplines, also.

That is, of course, a very difficult thing. Could I ask each of you for a thought on how you would arrive at recommendations for what the funding in this area should be? Maybe that is too general a question.

Dr. Juster has already sort of set out a pathway that seems a very constructive one, but one that is very difficult to give meaning to except in terms of the individual projects which you did lay out.

Do you have any guidance for the committee? How do you react to the fact that we are 22 percent below 1980 levels? What do you feel was really lost in that reduction? Do you have any advice to the committee on rationales for future funding? I know that is kind of a general subject and not really a direct question, but could I just ask you to give me your reactions and comments in that area?

Dr. Juster.

Dr. **Juster**. As you suggest, Mr. Chairman, it is a very difficult question. Let me put it this way: What has been lost would be very different if the support levels for the social and behavioral area continued on the same trajectory as they are now on.

Part of what happens is that the initial reactions of the National Science Foundation programs in the social and behavioral science to that kind of reduction is to say: "Let's hope that things recover and, therefore, let us adopt strategies which presume that things will recover in the future.

Thus, you don't eliminate whole areas of work initially. What you do is, you say well, we will take everything and cut it by a third. We will lop off a few fringes and try to make do temporarily with the hope that life will be better in 2 or 3 years.

That strategy is perfectly viable for a period of 1 or 2, possibly 3 years.

As a long-term proposition, it is not viable, so that what happens is what has been-lost is different if you measure it over the last 2 or 3 years than what would be lost if the same pattern of funding continued and that was regarded as the new level to which everyone would have to adapt.

There is an adaptation process involved here. A principal thing that has been lost is that a very large number of younger social behavioral scientists have been discouraged out of serious scientific careers.

We have had a half a dozen of our young people at the institution that I direct, the Institute of Social Research at the University of Michigan, who have decided that being in the business of pursuing a research career with grants from the Federal Government, either the National Science Foundation or elsewhere, is not a terribly attractive enterprise.

These are smart, bright young people, the kind you like to see encouraged.

Instead, half a dozen have been discouraged out and are doing different things. Graduate students that have a choice whether to go into the social sciences or the natural sciences, or go into something quite different, find there is little opportunity to become a graduate student research assistant working with a more senior professor on a project and being involved in the learning process.

Mr. WALGREN. Let me ask you this then, and the other members might want to comment: One approach would be to try to measure what is happening to the personnel area and whether or not there is the proper strength and commitment. In fact, as this develops to crisis proportions, we do that with engineering.

Finally, the Congress is putting all kinds of money there. Maybe the National Science Foundation ought to be telling you that they have evaluated the manpower commitment. To the best of my knowledge, I know of no such approach they take on an organized basis. What would happen if you took that approach to the social and behavioral sciences? What would they find?

Dr. JUSTER. I think the first thing you would find is it is difficult to get the relevant numbers. That is where you start.

I think in principle that would be correct. You could move in that direction. If you were to ask me whether or not it is possible to make a scientifc judgment about the value of $5 million worth of research in sociology or political science or economics or psychology, and $5 million of research in physics, chemistry, or molecular biology, my bottom line answer would be that if you try to make that comparison, it is a seat-of-the-pants judgment and you can't get much help from the scientists in providing you with those judgments.

We can make pretty good judgments about what ought to be done in molecular biology, or economics, or sociology, or anthropology. But if you start saying what is it worth to have this activity in molecular biology, or that in economics, you can talk about it in a general way and get a feel whether there is something exciting going on or whether it sounds dull.

The scientists themselves, if they are candid, will say, well, this set of things, that field is not buoyant right now. It could do with no growth. You will get people to admit to that kind of judgment.

Quite frankly, at bottom, it has to be a judgment which is outside of the scientific community because the criteria by which to make that judgment are simply not available. You need an estimate of the stream of benefits, the future benefits coming from these investments. We can't do that realistically. People have to look at what is proposed, at what is being done, at what is missing. They have to say to themselves, this sounds like an area grossly underfunded, slightly overfunded, or maybe not underfunded. That is what I tried to convey in the discussion. The evidence seems to be unambiguous, the social-behavioral level is grossly underfunded.

The scientific quality of the product is such that even in the 1970's, before the cuts, the social-behavioral program was at least as high quality as the physical and natural science programs.

There was an NSF panel which looked at that question—the Simon committee. They said: As best we can determine from the evidence, these programs are at least as high quality on scientific grounds as the ones in the physical and natural sciences. What they did was very inventive. They looked at the quality of rejected proposals and asked themselves which sounds more exciting.

Their conclusion was the social behavioral ones that were rejected were better than the other ones that were rejected. If that was true before the cut in 1980, it must be true in spades after the cut. Those are the kinds of criteria. They are quite vague. They are not quantifiable.

I would hope one of my colleagues could provide a more quantifiable way to do that. I can't think of any way to do that.

Mr. WALGREN. May I ask Dr. Leibowitz.

Dr. LEIBOWITZ. We seem to overlap in our approaches. I think the worst thing we can have is selective cutting.

As Dr. Juster points out, it sends a signal to young researchers. This is particularly bad in the behavioral sciences. Unlike engineering, physics, medicine, the people who go into the behavorial sciences decide rather late.

Most of our psychology majors knew nothing about psychology until they came to college. They decided late in their careers they were going to go into this field.

When you discourage students and young investigators by massive cuts, you really eliminate our most precious possession, our young people. I think it is worse in the behavioral sciences. I think what we need is an immediate signal to reverse this and say we made a mistake, that this won't happen again.

At least we should maintain parity with the other sciences.

You asked a difficult question about comparative funding. I think I appreciate the question. That is how do you decide what not to spend money on. I suggest that the NSF staff is in the unique position to make this decision. I said before that NSF was unique.

One of the points I had in mind was that unlike other groups in Washington, the staff of the NSF is very close to science. They come to panel meetings. They can discuss science at the highest levels in terms of interacting with researchers. That isn't true in other agencies. I think the NSF staff has a good feel in my experience for what fields are productive and which ones aren't, which ones are worthy of being supported and which ones aren't. I recommend them as the best possible source for helping you make this difficult, comparative budgeting decision.

Mr. **Walgren**. As some historical support for that, a little political in nature, it is my understanding the NSF staff never recommended any reductions in social sciences. This flowed from OMB, and I believe historically it will be seen as an example of the real Achilles heel of this administration.

This was that they drew a budget on a line by line basis out of OMB that then by political force was imposed on the Congress on the country, and on NSF.

That budget had none of the sensitivities which we rely on these other institutions to provide, and, therefore, it could not be reasonably responsive to the needs of the country, or the science in this area.

From my experience, your suggestion is certainly a positive one. If that decision were made by NSF, we would not have seen these kinds of cuts.

Mr. Wyatt?

Mr. **Wyatt**. Yes; I think that the National Science Foundation is essentially the pure research financier of last resort. It is a place where what is referred to as undirected research is financed; yet it is that kind of research that has produced much of the current watershed of technological activity, for example, recombinant DNA technology. The research goes back 30 years. If you look back to the threads of research that led to recombinant DNA technology, they were many in number. They essentially all derived from pure research.

My own feeling about it is that the country should just make a decision about a percentage of funds to put into this area. It should keep the judgments to be made on what gets funded in the peer group. That has been tested broadly. It has been tested well. It does work. In fact, it is a mistake to go down into the lines and start paring away. I think there are two issues there. First, to decide on a percentage of the gross national product to invest in this area and just do it. Then to keep the evaluation of the quality of research in about the same hands that it is now with periodic reviews and checks.

There is a third problem that was mentioned earlier I would like to just put another perspective on it. The problem is the reduced number of students coming into the research community, fewer students being encouraged to pursue research careers. There is a widespread problem there. It is not just in the behavioral sciences. It is in every scientific field. Even those students majoring in the hard sciences and engineering are being drawn away into the job market for two reasons: the cost of education is high and the demand in the work force is high for those people.

I really believe we have to get back to some form of merit scholarships in the sciences, broadly defined, that provide a means, a mechanism, whereby bright students can, without being directed where they must go, pursue their own course on a means independent basis.

Mr. **Walgren**. Mr. Dymally?

Mr. **Dymally**. Thank you, Mr. Chairman.

Dr. Juster, you were reluctant, with good reason, to be very specific about some of the programs that you think can be funded. So this question is really designed for a written response.

Would you write the committee and suggest some programs that could be targeted for funding?

NSF has a tendency to select safe projects or spread themselves so thin that everybody gets a little piece of the pie which ends up to be a crumb, and nobody gets enough to do something of any substance.

Dr. JUSTER. May I comment briefly? I am certainly willing to do that. I do cover some of that in the testimony. I am willing to give some thought to that and send the committee a note. I would say it is well to keep in mind that the procedure by which the NSF decides precisely what to do is only influenced by notions about program areas and in a quite indirect way.

The National Science Foundation can decide to have a program which broadly describes a set of research activities which that program is designed to support. Precisely what gets supported is not something which is—and quite properly so—at the control of anyone except the peer review panels at the National Science Foundation.

They review proposals that are sent in. They say this one looks very good; we should do it. This one, although it is interesting, isn't very good and we shouldn't do it.

That is the peer review process. It has its flaws. It is like a lot of other things. It is a terrible system, but is better than any other one anyboy has thought of yet.

I think it is well to keep in mind that having ideas about what kind of things can be pursued is not the same thing as having a project undertaken. Ideas will not necessarily eventuate in activities.

The peer review process is quite probably a bad way to allocate funds, but is probably the best of all the bad systems one can think of.

[The information follows:]

In addition to the research activities centered around the creation and analysis of scientific data bases, there are a set of other high-priority research activities that cannot be accommodated within the FY 1984 budget request.

> Theory of Markets. Economists have typically worked with a theory of markets which is deductively based--it makes inferences about behavior from assumptions about the objectives of decision-makers and the technical characteristics of production processes. Recent research in this area has tried to simulate the behavior of markets in an experimental setting. It turns out that market behavior can be reproduced in such experimental settings provided the subjects are given real incentives by payment schemes that depend on performance. The idea is provocative, since one can then examine the internal structure of various types of market in a way that would not be possible in natural settings.
>
> Moreover, the use of experimental methods can be extended to markets in which there are no prices--bureaucratic decision processes can be thought of as a kind of market, as can political decision processes. But this work is expensive, and cannot be continued on an appropriate scale within the budget request.
>
> Statistical Methodology. There are at least two important areas in which the development of new statistical methods is possible but not capable of implementation.
>
> One is the development of new methods for handling longitudinal data, obviously important as an adjunct to the creation of these relatively rare and new types of data. The error structure in longitudinal data is somewhat different than in other types of data, and new methods need to be developed.
>
> It is now recognized that one of the problems with the performance of macroeconomic modeling systems is that a basic assumption made in such models--that the underlying structure of the economy is stable--is highly questionable. Estimation methods to deal with a variable underlying structure can be developed, but again they are expensive and precluded within the budget request.

Applications of Basic Knowledge. The U.S. courts are clogged with civil suits dealing with litigation relating to divorce, accidents, industrial compensation, etc. These suits impose enormous burdens and costs, and there is some evidence to suggest that mediation is both more cost-effective and more mutually satisfactory in such cases than jury trials. Experiments could be designed in which the benefits and costs of mediation and jury trials could be assessed.

The costs of crime in U.S. society run into the tens if not hundreds of billions annually. Reduction of these costs depends on identifying effective systems of deterrence, a problem which could be addressed with the combination of longitudinal data relating to the individuals who commit criminal acts and parallel data relating to the organizational processes which determine convictions, punishments, etc.

The set of research activities outlined above, which cannot be accommodated within the FY 1984 budget request, is obviously a very idiosyncratic list of items: if someone else had been testifying before the Committee, the list would be different although there would doubtless be some overlap.

What would be the benefits and costs of implementing this addition to the budget request? For most of the activities that I have specified, the benefits would be difficult if not impossible to quantify. For a few areas, one can provide a rough indication of potential orders of magnitude. Both the studies of saving behavior and of organizational effectiveness have their ultimate payoffs in terms of the productivity growth rate in the U.S. economy. Even small impacts on productivity growth have enormous societal payoff--for example, a one-tenth of one percent improvement in the annual productivity growth rate provides an annual societal return of roughly three billion dollars at current prices. It is not difficult to imagine that a full understanding of the dynamics of saving behavior, or the way in which organizational factors relate to organizational productivity, could easily amount to a one-tenth of one percent annual gain. In the area of criminal deterrence, even a small reduction in the billions of dollars of costs that criminal activity imposes on U.S. society would repay very large dividends. In both these cases, the potential benefits run into the billions while the potential costs run into the tens of millions at most.

On the cost side, I have made an attempt to price out the specific research activity discussed above--saving behavior, organizational effectiveness, time use and nonmarket activities, changes in family ties, the theory of markets, statistical methodology, civil suit mediation, and criminal deterrence. In all cases, I am talking about a program of work that needs to continue for a good many years. (The Committee should be aware of the fact that decisions about the specific content of research activity cannot be made by outlining areas of research in which important scientific or policy objectives can be realized. Research activities are determined by a peer review process internal to the NSF, as is entirely appropriate).

The annual cost of the set of activities outlined in my testimony comes to roughly $12.5 million. Since these programs cover something like 40 percent of the total social and behavioral science programs at the National Science Foundation, and on the assumption that the program areas I have not discussed have the same potential as the ones noted in my statement, the $12.5 million annual cost figure turns into an annual cost of $30 million.

Although I think one can make a persuasive case that a definable set of high priority program areas would justify a budget increment of $30 million in FY 1984, I could not recommend that to the Committee. Programs of research cannot be quickly turned around if research funds are to be spent wisely and cost-effectively.

But I would argue that there are major untapped potentials in the social and behavioral science programs at the NSF that cannot be accommodated within the budget request, that a plausible order of magnitude for the cost of these programs is something like $30 million, and that a sensible procedure would be to provide resources for implementation of these types of programs over more than one year. For example, the Committee could recommend an increase of $10-15 million in this year's budget, with a recommendation that the programs be incremented by an additional $15-20 million the year after. That would bring the social and behavioral science programs to the point where available resources would permit realization of scientific potential in these areas to the same degree that resources permit scientific potential to be tapped in other areas.

In summary, I would urge the Committee to provide significant expansion of resources in the social and behavioral science area in the FY 1984 budget, and to recognize that this represents only a partial step toward implementing the appropriate scientific priorities within the NSF.

Mr. **Dymally**. Chancellor, this is not a committee-related question, but has to do with medical science. You probably have not been at Vanderbilt long enough to answer this one so I will solicit your response in writing.

Has the hospital problem between Meharry and Vanderbilt been resolved?

Mr. **Wyatt**. I think the answer to that is yes. David Satcher and I are both new to the community. We are communicating on a regular basis about the problem. We are very pleased with the progress that is being made there.

Mr. **Dymally**. Thank you very much.

Dr. Satcher, I would footnote, came from the Charles Group Postgraduate School which is located in my district, and then to Morehouse and, of course, to Meharry. We stay in touch with each other too.

Thank you, Mr. Chairman.

Mr. **Walgren**. I have to go to another commitment. I apologize. I do want to say I appreciate the commitment you all have made.

I am going to ask Mr. Boucher to chair the rest of the hearing. I know he will have thoughts to share with you.

Mr. **Boucher** [presiding]. I have one question for Mr. Wyatt. I understand you have been supportive of the Foundation's involvement in research in the area of computer networks.

If you could make a comment or two concerning the significance of that research and the implication that it might have for the use of super computers and access to those in the years ahead, I would appreciate it.

Mr. **Wyatt**. Well, let me say that in one of my prior incarnations, while at Harvard, I served as chairman and chief executive officer of an organization called EDUCOM, which, among other things, established, during the time I was chief executive officer, a national network among colleges and universities.

That, in fact, is now in use, rather widespread use, and it allows scientists, students, anyone at the university access to remotely located resources, software and hardware, that exist at other universities. I am very much committed to the fact that this is a useful activity. In our initial stages, we developed with NSF sponsorship a computer-based model to test the hypotheses about the use of such a network, about the kind of traffic that would be on it, about the kinds of use that would be made of it. That was a very successful activity. It called together a collection of some 50 university executives and scientists to participate in a large simulation exercise, after which the network was started. The EDUCOM network called EDUNET, continues now with several hundred ports into which people can access the resources of the network. We developed a philosophy there that we would use commercially available communications resources and not ask for a massive program of special networking. That turns out to have worked rather well. The ARPANET technology was developed under the leadership of Larry Roberts, who later founded TELENET, now a multinational company by virtue of being acquired by ITT. Their service has worked rather well. We are also able to use TIMENET.

The hypothesis has been demonstrated that such networks are very useful. They are particularly useful in two areas: One is to access large collections of data that are very difficult to move. In fact, the collection of data at the University of Michigan is one such collection. The other is to access large algorithms that are also difficult to move. Those at the National Center for Atmospheric Research come to mind.

It is almost a necessary condition in my mind that supercomputers oriented to special kinds of problems—and I expect that they might be so oriented by virtue of their design, suggest the capability to access those supercomputers through a network. I, also, believe it essential for scientists to visit these facilities on occasion, but it shouldn't be necessary to visit the facility physically in order to use it at all. So I think networks will be absolutely essential.

Mr. BOUCHER. Thank you. I do have one additional question.

I would be interested in your comments concerning the comparative use of information science and technology in this country vis-a-vis some of our principal international competitors, in particular Japan and West Germany.

Are we lagging behind? If so, in what ways would you suggest we undertake the effort to catch up?

Mr. WYATT. I think that is a serious problem. We, of course, in this country, invented most of the technology, particularly the information technology, that in some sense is being implemented much more ably by Japan. The manufacture of automobiles is a very good example. We invented the basic technology that now is being used for automating the manufacture of automobiles. We prototyped it in this country in the late 1950's and yet our automobile manufacturers did not implement it. There is a problem of implementation, and we simply have to get about that in this country. I see some promising signs, but I see that we are a ways, a good deal far distant, I think, from achieving some of the gains that are being seen by the Japanese and Western Europeans in implementation of technology. All of this technology is based on and derived from basic research activities. Much of that research was financed by the National Science Foundation. Now we are entering an era where the productive use of this technology gets quickly into behavioral issues, So I am concerned that we keep up, perhaps even accelerate research in the behavioral areas that relate to technology. We are talking about very modest numbers, as has been pointed out by Dr. Juster

While we are attacking the problem of implementation of technology, much of which can be done by the private sector, we really do have to worry about the basic research that will not only relate to technology, but, also, its use in the basic science areas.

Mr. BOUCHER. At this time I will call on the minority Counsel, Ms. Bach, for questions.

Ms. BACH. No, thank you, Mr. Chairman. I have no questions at this time.

Mr. BOUCHER. Mr. Maxwell?

Mr. MAXWELL. Thank you, Mr. Chairman.

Mr. Brown asked that a couple of questions be addressed specifically to Mr. Wyatt. Last year members of the Science Committee received a letter signed by 30 distinguished scientists including Nobel Laureates from Physics, Biochemistry, and Economics, urging increased support from the NSF for information science. That certainly follow the thrust of the testimony you presented.

In your opinion, are there special features of information science which make it worth nurturing and can it properly be nurtured at current levels as suggested in the present budget presentation both in terms of support regarding funding as well as the type of management support that we currently find at NSF?

Mr. WYATT. I think information technology now cuts across practically all human endeavor. It certainly is cutting across all research programs in the Foundation. Dr. Juster just mentioned that one-third of the use of the computer facilities at the University of Michigan is devoted to the behavioral sciences. That is just an example of the involvement of information technology as a tool for research in all fields. It is a matter of concern all across the Foundation. I believe it should be given continual attention. It was given attention in the Leesburg convocation of all of the research activities that relate to information technology, communications, computer science, and engineering. Perhaps another examination could and should be made of those areas of research that require special instrumentation in order to achieve certain results that depend on information technology.

For example, I just visited the molecular biology laboratory at Vanderbilt. It was brought home to me again how much instrumentation is a factor in being able to move these frontiers forward. It simply is absolutely necessary. If the technology is not available, certain kinds of work can't be done. That is becoming more and more true in more and more fields. Certainly the fields include economics, biological, and behavioral sciences.

Mr. MAXWELL. The funding support levels as currently proposed would bring us basically on par with what had been a fiscal year 1981 level for the information sciences in BBS. In comparison with computer engineering, where we are seeing a 25-percent increase compared to last year, within the computer research activities, we see a 19-percent increase. That seems to leave us somewhat behind in the information sciences.

Do you have any suggestions as to the level of additional support that may be considered by this committee to allow some of these activities to move forward as you suggested?

Mr. WYATT. As others have pointed out, it is very difficult to specify too particularly in this area, but I see no argument that would cause me to believe this area shouldn't be pushed absolutely as hard as any area that is being pushed. It has to be a national priority. It is one that is at the core of so much of our research and our education and will be in the future that we simply have to push it as hard as we possibly can. I think that any allocation of funds that is aggressively represented would have to include information science and technology.

Mr. MAXWELL. One final question.

Again considering this type of support, in looking outside of the National Science Foundation, are you aware or can you tell us what the level of private sector support for information science and technology is and how that compares with what the National Science Foundation proposes, as well as with other programs outside of NSF within the Federal Government that address this?

Mr. **Wyatt**. Of course, the private sector is making heavy investment in this area. I just did a piece on future employment in the United States relative to the effects of technology and discovered that in the automated factories that will be competitive in this country—we are talking about productivity improvements of a factor of 30 and profitability improvement factors of 10 or more. In order to be competitive on a worldwide basis, our private sector simply has to be able to accommodate and have incentives for this kind of implementation of technology.

The point was brought home again only two days ago by an editorial in the New York Times that said "along with the technology comes significant behavioral issues." The editorial to which I am referring said that 95 percent of middle management feels insecure about the implementation of technology in the work force. Certainly after having taught in various executive programs at Harvard where I saw a collection of middle level executives from all parts of the economy I would certainly support that. We have an issue here that simply must be addressed. One of the reasons that we felt it was important for IST to be very close to the biological and behavioral sciences, particularly the behavioral sciences, was this problem of the absorption of the effects of technology into the culture. The problem is going to become much greater in the near term future.

In some sense, young people deal with technological change better than older people. However, the problem does relate to all students in school.

We need to address that issue. But we are also talking about the population in general; every part of the population will be affected.

Mr. **Maxwell**. Thank you very much, Mr. Wyatt.

There may perhaps be some questions for the record in addition to these.

Thank you, Mr. Chairman.

Mr. **Boucher**. Thank you, Mr. Maxwell.

Gentlemen, I would like to thank all of you for being with us today. Your testimony has been very helpful to the subcommittee in our consideration of the National Science Foundation budget. Thank you for your assistance.

Our final witness for today is Dr. James Rosser, president of the California State University at Los Angeles.

Dr. Rosser will be providing testimony on the National Science Foundation's proposed management plan and its implications for minority programs.

Dr. Rosser, we are glad to have you with us this morning. We will be pleased to receive your statement.

STATEMENT OF DR. JAMES ROSSER, PRESIDENT, CALIFORNIA STATE UNIVERSITY AT LOS ANGELES

Dr. **Rosser**. Thank you. It is a pleasure for me to be here today to offer testimony in this regard. I am president of California State University at Los Angeles, a position I have held for the last 3½ years.

Prior to assuming my present position, I worked for a period of time as the deputy chancellor of higher education in the State of

New Jersey and senior associate vice chancellor for academic affairs at the University of Kansas.

I am a health scientist by background and training and worked for a period of time as a cancer researcher in the private sector.

I am pleased to have the opportunity to appear before this subcommittee today to testify on the proposed management plan of the National Science Foundation.

Before presenting our views on the proposed management plan, let me say a few words about our institution.

California State University, Los Angeles, is a unique, urban, metropolitan university with one of the most ethnically-diverse student bodies in the country Asian, black, and Hispanic students are all significantly represented on our campus and constitute over 65 percent of our 22,000 students. Most of our students, whose median age is 27, come from low-income families and more than half of them work full or part-time.

We have placed particular emphasis on academic programs designed to increase the numbers of minorities in the sciences and other math-based fields. Not only are these the fields in which minorities are severely underrepresented, but they are also the fields which represent the greatest opportunity for employment in the future and are vital to this Nation's future well-being at home as well as in the world community.

Despite public funding limitations and the heavy teaching loads of our faculty, we believe that we have been highly successful in preparing our students for these future opportunities.

Although we have had some experience with NSF research programs, the success we have achieved with our minority students can be largely attributed to such programs as the minority biomedical research support [MBRS] and the minority access to research careers [MARC] programs funded by the National Institutes of Health. We definitely need increased support from the NSF and other Federal agencies if we are to extend our efforts to serve larger numbers of minority students and, therefore, the Nation.

This brings me to the proposed NSF management plan. From our discussions with NSF personnel and Members of Congress, we understand that the plan would distribute the responsibilities for minority programs among all of the directorates.

Currently, as you know, these programs are located in an administrative unit not attached to any one of the directorates. The establishment of this unit was apparently intended to give these programs greater cohesiveness and visibility. While the unit has done a commendable job and provided support for a discrete number of minority institutions, from our perspective, there are a number of problems with the current management structure.

First, the programs have suffered from inadequate funding. The demand from historically-black institutions alone has far exceeded the availability of funding. Second, the functional definitions used by the NSF to qualify an institution as a "minority institution" are ambiguous at best and, in our opinion, have failed to meet the intent of the Congress.

In our case, we have applied to the NSF for minority programs in the past only to be told repeatedly that we were not eligible. Given the fact that we have the largest enrollment of minority students in absolute numbers of any four-year institution in the continental United States, we were more than a little perturbed by the incongruity of this ruling.

Third, the rest of the NSF units, which administer the major share of the Foundation's funds, seem to pay little attention to the needs of minorities and often relegate such efforts to the small unit that administers minority programs.

Lastly, the general thrust of the NSF has traditionally been toward increased support for research-oriented, majority institutions. While this mission-oriented thrust may be understandable, I wish to point out that it seriously limits the efforts of universities such as ours, which enroll the bulk of minority students, to provide such students with opportunities to participate in high-quality research programs and to prepare them for research careers.

On the face of it, the proposed plan could be a vehicle to overcome the difficulties I've described. By having the entire Foundation through each of its directorates take direct responsibility for minority programs, the resulting impact could conceivably be far greater than that of the present structure.

But before elaborating on the advantages of the plan, let me mention some potential problems that may arise if the design and implementation of the plan is not done with sensitivity and care, and if the emphasis is not on realistic expected outcomes for the Foundation as a whole.

I believe the major problem that may arise is that the proposed plan will lead to a dilution of effort. The directorates may give minority programs such low priority that they will have little visibility and lose whatever identity they may have. As a result, many institutions of higher education may not be aware of their existence or may have considerable difficulty gaining access to the appropriate offices and individuals.

Furthermore, without a specific allocation for minority programs in each of the directorates, funding for these programs may suffer or disappear altogether. At least under the present structure, there is a single unit that is centrally concerned and serves as an advocate for minority programs.

Another serious problem may be the lack of uniformity in how the various directorates prioritize and implement programs targeted for minorities. It is possible that some directorates will be more conscientious than others in promoting such programs. There may also be a lack of consistency among the various directorates regarding policies and guidelines applied to these programs. In fact, we encountered such a problem in one of the existing NSF programs, the research improvement in minority institutions or [RIMI] program.

Although we submitted an application to this program confident that we met the eligibility requirements, we were informed that our institution did not qualify for the program even though we qualified for another program, the minority institutions science improvement program or [MISIP], which has eligibility criteria identical to those of the RIMI program.

Inasmuch as the eligibility requirements for the MISIP were originally developed by the NSF, where it was located before it was transferred to the Department of Education, it is difficult to comprehend any logic behind the NSF's ruling on our RIMI application.

One other potential problem I wish to mention is the increased bureaucracy that may result from the new management structure. Under this structure, institutions will have to direct their inquiries and proposals to several offices as opposed to one, perhaps wasting both time and resources. Moreover, if minority program functions are distributed throughout the Foundation and accountability is not clearly and specifically assigned to the various management levels, it may be difficult to identify the offices or individuals who have the responsibility for making decisions and setting policy. In other words, everyone may "pass the buck" and the "buck may never stop."

I believe the problems I've mentioned can very likely be overcome. In fact, with careful planning, collaboration and foresight, I think the evolving managment plan could have several advantages over the existing structure.

However, if these advantages are to be realized, I believe it will be necessary for the NSF to reassess its current efforts to increase the participation of minorities in the sciences and other math-based fields. Minorities continue to represent a large and largely untapped pool of human resources that could be harnessed to meet the increasing manpower needs of our scientific and technological enterprises, including all levels of education.

I would suggest, therefore, that it is a most propitious time for the NSF to increase significantly its overall commitment to minority programs. Assuming that such an increased commitment is forthcoming, let me briefly discuss how I think the new management plan might work to the advantage of these programs.

First, by spreading the responsibility for minority programs across all of the directorates, the available funding for these programs could conceivably increase substantially. Currently, these programs are primarily oriented toward training, not research, and tend to be isolated from the research programs in the directorates. Yet, the vast majority of the NSF budget is committed to these mainline research programs.

Therefore, if the new management plan sets specific performance objectives and holds the directorates accountable for meeting these objectives, it could lead to a considerable expansion of efforts and to a corresponding commitment of additional resources. Let me again underscore that it is imperative that priority for continued funding be based on achievement of previously articulated objectives.

Second, by involving the entire Foundation in these efforts and increasing its commitment to minority programs, opportunities to participate in these programs may be broadened to a larger number and variety of institutions having significant numbers of minority students. Currently, only a small fraction of such institutions participate in these programs.

For example, no college or university west of the Mississippi, with the exception of Pan American University in Texas—and three or four others—can qualify for the RIMI program under the NSF's current interpretation of the eligibility criteria.

By establishing more logically consistent eligibility criteria which have a clear correlation to the desired outcomes, the new management plan should enable institutions like ours, which enroll far more minority students than most of the currently eligible institutions, to participate in these programs and contribute in a major way to meeting their objectives.

Finally, the integration of minority programs into all of the directorates could be a major step toward providing minorities with access to the mainline research programs of the NSF. Such access would facilitate direct contact and familiarization with the relevant program managers and help broaden the expertise of minorities in all of the scientific and technological areas.

Conversely—and just as importantly—each of the directorates would have to become much more knowledgeable about the problems associated with minority underrepresentation and more committed to addressing them. Such a process could increase significantly minority participation in the mainstream scientific and technological communities of our society.

Based on the analysis I have presented on the potential problems and advantages of the proposed NSF management plan, I would like to present for your consideration the following recommendations:

First, that at least for a reasonable period of time, an office be established directly under the NSF Director with the responsibility for overseeing the development of minority programs in each of the directorates and for monitoring the progress of these programs. This office might also function as a clearinghouse to provide information to assist institutions and individuals in gaining access to programs in the various directorates. If the efforts of this office are successful, the need for it should eventually disappear.

Second, that the NSF, concomitant with its implementation of the new management plan, take steps to insure that the directorates give sufficiently high priority to minority programs so that the total resources committed to these programs increase substantially.

Third, that consistent eligibility criteria be established that will not exclude institutions that should logically qualify but, rather, will broaden the participation of institutions having significant numbers of minority students.

Fourth, that well-defined and specific performance objectives be formulated to help guide the efforts of each directorate in developing minority programs and that corresponding evaluation criteria be formulated against which the performance of each directorate will be measured for continued funding. In other words, each directorate should be evaluated on the basis of results.

Fifth, that each directorate be required to develop a plan decribing how it will develop its minority programs and meet the specified performance objectives, and that the National Science Board then consolidate these plans into an overall plan for the Foundation.

Sixth, and finally, that the National Science Board review annually the performances of the directorates and of the Foundation as a whole in meeting its established minority program objectives.

In closing, let me say that I know there are many serious challenges facing this Nation in the next several decades. How we move from the post-industrial to the knowledge-based or high-technology era is a major concern. The efforts of the NSF to generate both the necessary personnel, research and knowledge to meet the needs of society during this transformation are crucial.

I see it as a three-pronged responsiblity. I believe questions were raised this morning about the personnel as well as the research and knowledge responsibilities that exist at this level.

I am firmly convinced that the large and largely untapped pool of minorities in this Nation, whose numbers are projected to continue to increase dramatically over the next few decades, provides an indispensable human resource that must be utilized to meet these needs.

It has been with that thought in mind that I have presented our analysis of the proposed management plan and our recommendations on how we we think it may be effectively implemented. I hope you will find both the analysis and recommendations useful in your deliberations and that you will arrive at a management plan which will insure the success of NSF efforts to develop the minority human capital of this Nation. Thank you very much.

Mr. BOUCHER. Thank you, Dr. Rosser, for that very thoughtful testimony.

Mr. Dymally.

Mr. DYMALLY. Thank you, Mr. Chairman.

It might be helpful to explain Dr. Rosser's presence here. My office was in a state of shock when I found out that California State, Los Angeles, 66 percent of minority, was not eligible for NSF funding. I suspect they use the historically black colleges as a pool to provide funding, ignoring in my district 100 percent black and minority students coming to a college that would not be eligible.

Easterners have this bias against the west coast, especially in funding—and I find it among all segments of the Washington community. The reason is that they look at minority colleges in the context of a list of historically black colleges.

Dr. Rosser, a question I wanted to ask you is about what you think the NSF ought to be doing to look at the emergence of these new urban minority schools in setting up new criteria. Should, for instance—I think a similar situation may arise in Chicago, too, that parallels your school.

Dr. ROSSER. I don't believe there is a school similar to Cal State Los Angeles, in Chicago. The problem, I guess, involves our Asian student body, as perhaps you know. But it would seem to me that your point is well taken, given national demographic statistics pertaining to urban areas.

Hispanic students who reside in California and other parts of the Southwest have had virtually no opportunity to participate in the RIMI program.

Mr. DYMALLY. Los Angles has the third largest Hispanic-speaking population in the world. The State of California in the next decade will become the first Third World state other than Hawaii. So the demographics, it seems to me, would really dictate some reexamination of NSF policy.

Dr. ROSSER. I believe, Mr. Dymally, the Foundation does not place Asian-Americans on its list of those underrepresented in the sciences.

Mr. **Dymally**. But the National Research Council has stated that there is underrepresentation of American Asians in math and science. What has happened is that the newcomers, those who come with prepared skills, are included in that statistic, and thus they come to the whole situation as it exists in Los Angeles, for instance.

Dr. **Rosser**. One would hope perhaps, then, that maybe some adjustment might be made relative to this in terms of American-born Asians versus Asians who migrate to the United States. It is very true on the national level that significant numbers of Asians who are part of our high-technology work force are individuals who come to this country already with credentials in these areas.

Mr. **Dymally**. There must be a number of "historically black colleges" with less minority students than you and probably more white students. At the one I went to, Lincoln University, there are more white students than there are black students. That is in the State of Missouri.

Dr. **Rosser**. We have more black students than probably about 70 percent of the historically black colleges. We have almost 3,500 black students.

Mr. **Dymally**. Mr. Chairman, I want to thank the panelists, and thank Dr. Rosser for coming. I would like very much to have Dr. Rosser's testimony submitted to the Director of NSF and to have included in the report language, when we submit it to the full committee, this whole dilemma which is faced by California State at Los Angeles.

Thank you very much.

Mr. **Boucher**. Very well. Thank you, Mr. Dymally.

Dr. Rosser, I have only one question of you. I noticed during your testimony you stated that Asian-Americans are presently not placed on the National Science Foundation's list of those underrepresented in the sciences today.

It occurs to me that perhaps at New Mexico University, at universities in Arizona there must be a significant population of students from Mexican-American backgrounds or perhaps who are Native Americans. Do you know if those individuals are presently characterized as underrepresented in the sciences also?

Dr. **Rosser**. Mexican-Americans are presently characterized as being underrepresented. Interestingly enough, Mr. Boucher, in terms of the RIMI program in particular, I believe there are only about two institutions that enrolled a significant number of Mexican-American students that would be eligible.

Another interesting aspect of this is that many of the RIMI institutions do not have engineering programs. As a matter of fact, of the four programs which were funded by the NSF I believe only two of the four had engineering programs. So, within the context of the objectives of the RIMI program, the ability to provide comprehensive access was apparently not a consideration.

Mr. **Boucher**. I think you have certainly highlighted an important concern here. On behalf of the subcommittee, I would like to thank you for making the long trip to Washington to make this testimony available to us.

Dr. **Rosser**. It is my pleasure. Thank you.

Mr. BOUCHER. That does conclude our hearings on authorization of the National Science Foundation's budget. The committee will be meeting on March 17, next Thursday, for its markup session. That concludes our hearing. At this point I would like to insert some items that have a bearing on the subject of today's hearing. The committee will rise.

[Whereupon, at 12:30 pm., the subcommittee was adjourned, subject to the call of the Chair.]

[The information follows:]

[A statement for the record on STIA Budget and Responsibilities, by Robert P. Morgan (Brookings Fellow)]:

ON THE NSF-STIA BUDGET AND RESPONSIBILITIES

by

Robert P. Morgan*

3/10/83

I wish to raise some questions and concerns about the FY '84 National Science Foundation budget, particularly that portion of the budget allocated to the Directorate for Scientific, Technological and International Affairs -- The STIA Directorate. In a year in which the total NSF budget request of FY '84 is 17.8% above the FY 1983 Current Plan, STIA's budget has been reduced from $44.2 million to $36.8 million, a reduction of 16.7%. Whereas in FY 1983, STIA accounted for 4.2% of the total NSF Research and Related Activities Appropriation, in FY 1984 that figure falls to 2.9%.

The rationale for this reduction in the STIA budget is set forth both in NSF budget documents and in a memorandum from the NSF Director, Edward A. Knapp, to the NSF Executive Council dated January 12, 1983. 1/ In that memo, programs included in the STIA sphere are characterized as being special programs which are stated to have not been viewed, implicitly at least, "as being as central to NSF's mission as the research directorates". Concluding that the responsibilities of the research directorates have been too narrowly defined, and that the special programs have not had sufficient resources to have an appreciable impact, Dr. Knapp articulates a new management philosophy in which the research directorates "must have sole responsibility for receiving, evaluating, and decisionmaking on all proposals (with the obvious exception of education)". STIA will continue to exist but it will primarily serve an agency-wide coordinating role. Furthermore, STIA's FY 84 budget request, according to the NSF Budget Summary to the Congress, is "an apparent decrease of $7.4 million"; however "an estimated $22.1 million within the Foundation's discipline oriented research activities will bring the effective total of the various NSF programs shown in this activity to 58.9 million". ——— an (actual?) increase of $14.7 million or 33.3%. 2/

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* Science and Public Policy Fellow, The Brookings Institution, Washington, D.C. 20036. (On leave as Professor and Chairman, Department of Technology and Human Affairs, Washington University, St. Louis, Mo. 63130.)

There are three issues that I wish to address which arise from these developments. The first concerns the efficacy of the proposed management plan -- that is, will it work as intended? The second focuses on the Foundation's ability to carry out its international program responsibilities. The third deals with the apparent decline of interest within the Foundation in interdisciplinary, problem-oriented research.

1. On The New Management Scheme

One premise upon which the scheme is based is that a more optimal program will result if the research directorates assume responsibility for decisions on proposals which heretofore were in the special program category, while STIA assumes a coordinating role. Because of this expanded responsibility, the research directorates will take more interest and the net result will be an even greater involvement overall within the Foundation in STIA-type program activity, or so the scenario goes. To ensure a successful transition, minimum spending levels for STIA-type activity within the research directorates will be set.

If the above works as intended, it could be a good thing. However, will it? For one thing, many details need to be worked out. The research directorate-STIA interface is likely to be more complicated than heretofore. Furthermore, unless there are some personnel changes which result in the research directorates becoming more sympathetic and sensitive to STIA-type activity, there may very well be problems. The FY 1984 Budget Request for Program Development and Management within NSF increased by only 1.1% and the number of Full-Time Equivalent Staff is projected to fall from 1,218 to 1,194. This reduction would not seem to augur well for implementation of a new, somewhat complicated management scheme.

2. International Programs

In FY 1982, International Cooperative Scientific Activities was the biggest line item in the STIA budget at $11.6 million. It slipped to $9.9 million in FY 1983 New Obligational Authority and falls to $5.0 million in FY 1984, a 1983 to 1984 drop of almost 50%. It is now a poor third behind Industrial Science and Technology Innovation ($16.5 million) and Research Initiation and Improvement ($6.5 million). However, two items appear within the research directorates; an additional $5.9 million for International Cooperative Research

Activities, and $2 million for a new U.S.-India Joint Program. Thus, in the NSF Press Release on the FY 84 budget, a total program for International Cooperative Scientific Activities of $12.9 million is shown, as is a % change FY 84/83 of plus 30.3%. 3/

Will the new management scheme have the intended multiplier effect on international cooperative science at NSF? It seems to me likely that certain kinds of activities may benefit, namely highly specialized areas of relevance to advanced industrial countries and those compatible with the present interests of the research directorates. On the other hand, NSF activity related to less developed countries and of a more applied nature may very well suffer.

Elsewhere, we have examined the mandate for NSF's international involvement, 4/ a mandate which has been receiving renewed attention by the National Science Board. 5/ NSF's legislative mandate would seem to provide sufficient justification for expansion of its international science and technology role, should it choose to do so. However, in the past its main international cooperative science activities have been with the developed countries. In NSF's 1979 budget submission, of the $10.6 million requested for International Cooperative Activities, 58% were for Cooperative Science Activities primarily with developed or wealthier developing countries; 31% was for Scientific Organizations and Resources, the largest single part of which was the U.S. share of the budget for IIASA.

Since 1979, the National Science Foundation's International Activities directed towards developing countries here had a difficult time. A reasonably successful program called SEED (Scientists and Engineers for Economic Development) funded by AID was terminated. A newly consolidated program, Science for Developing Countries, created at the time of UNCSTD, has had a difficult time getting off the ground with very small funding; components included dissertation grants for LDC students in the U.S., short courses, cooperative projects, etc. The budgeting history has run $300,000 FY 81, $200,000 FY 82, $500,000 FY 83.

NSF has a special role to play in connection with so-called AID-graduate or middle-income countries. About thirty bilateral agreements for scientific and technical cooperation are administered for the U.S. by NSF and up until now, they have been centered in the International Programs Division of the STIA Directorate. NSF also asserts that a great deal of international activity goes on outside of STIA, supported by the traditional scientific research directorates. A new $2 million item in the NSF 1984 budget submission is for an expanded bilateral program with India in the wake of Mrs. Ghandi's summer, 1982 visit.

In my opinion, international programs involving developing countries, particularly middle-income ones, have been far less than they could have been in the past at NSF. That being the case, it is certainly conceivable that the proposed change in program management and control will be for the better. However, I remain skeptical.

Scientific cooperation with developing countries has elements associated with it that require priorities, skills and insights which may be missing in the research directorates. Somewhere, a strong, knowledgeable presence in tune with the requirements for cooperation with developing countries is required. A strengthened rather than a weakened STIA with a higher minimum floor for developing country activity is an alternative worth considering.

3. On Interdisciplinary Research

The reduction of the STIA budget and its lessened role compared to the research directorates has a certain analogy with what is going on in the universities. In the 1960s and 1970s a variety of problem-focused interdisciplinary programs arose centered around key problem areas facing society -- energy, environmental quality, health care, international development to name a few. At NSF, there was Interdisciplinary Research on Problems of Society (IRPOS) and then there was Research Applied to National Needs (RANN) and now there is STIA.

Within the past two years, there has been a swing back towards the disciplines and away from interdisciplinary activity. I see the NSF-STIA situation as a part of that trend. The NSF Director, (who headed one of the key research directorates prior to becoming director) upon observing that "unfortunately, these special programs typically have not had the resources to have an appreciable impact", could have concluded that what needed to be done was to give the special programs more control of more resources.* He didn't. Disciplinary programs may suffer from some of the same maladies attributed to the special programs -- lack of impact and service only to special interests, i.e., the scientists within the respective disciplines.

In a broader sense, the new NSF budget can be viewed as another step away from the kind of interdisciplinary activity which became prominent in the 1960s and 1970s towards a more narrow conception of science as it existed before then. Such a development is occurring when the need for interdisciplinary research and focused activity is greater than ever. It should not go unchallenged.

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* There may also be some relation to the fall off in funding for applied civilian research in other government agencies, like EPA and the Department of Energy.

Footnotes

1. "The Management of NSF Programs, Memorandum from Edward A. Knapp to NSF Executive Council, January 12, 1983.

2. "Budget Summary to the Congress", Fiscal Year 1984, National Science Foundation, Washington, D.C. 20550.

3. "Statement of FY 1984 Budget", National Science Foundation News, NSF PR83-6, Feb. 1983.

4. Morgan, R.P., "Science and Technology for Development: The Role of U.S. Universities", Pergamon Press, New York, 1979. Chapter 1. (with E.E. Irons, et. al.)

5. "Statement on Science in the International Setting as adopted by the National Science Board at its 238th Meeting on Sept. 16-17, 1982.

[Two letters from the American Psychological Association with attached materials:]

American
Psychological
Association

March 14, 1983

The Honorable Doug Walgren
Chair, Subcommittee on Science,
  Research and Technology
U.S. House of Representatives
2319 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Walgren:

In the hearings that you chaired last Thursday on the National Science Foundation's Biological, Behavioral, and Social Sciences Directorate (BBS), witnesses testified that many young people were being discouraged from entering research careers in the behavioral and social sciences, in part because of chronic funding problems in these areas. You inquired explicitly about what was happening to research personnel in these fields. The purpose of this letter is to provide some data in response to your inquiry, and to comment briefly on NSF's impact on the status of research personnel.

We have looked at the number of first-year enrollments in the relevant areas of research, and the number of doctoral recipients. Attached are several tables of data, which, summarized, indicate the following points:

- The number of doctorate recipients in social sciences other than psychology decreased 15% from 1976 to 1981, and is roughly at pre-1972 levels (Table 1).
- This trend is also seen in research psychology, where the number of doctoral recipients declined during the same period (Table 2).
- First-year enrollments in research psychology fields declined by 25.5% from 1975-1980. If this trend continues, there would be only 758 doctoral recipients in these areas in 1986 -- roughly the same as pre-1970 levels (Table 3 and Figure 1). In other words, in terms of doctorate production, research areas in psychology will be back where they were nearly twenty years earlier, a condition which if continued for more than a few years will seriously threaten the quality and stability of several subfields.

These trends are not the result of an excess supply of research psychologists. In recent years, despite anecdotal claims to the contrary, psychology has not had an unemployment nor an under-employment problem. Our data consistently indicates less than 2 percent unemployment among psychologists.

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There is general agreement on at least four major causes of these trends, and they are directly related to federal policies.

1. One cause is the decline in recent years in the academic market for behavioral and social scientists. This same trend has affected nearly all of the scientific fields. Despite the employability of research psychologists in non-academic settings, it is likely that a shrinking academic market discourages potential entrants for many fields.
2. Second is the decline from an already very low base of federal research funds. This has been a chronic problem, as documented in the 1976 Simon Committee report from the National Academy of Sciences, but has gotten worse under the current Administration.
3. Within the total amount of federal research funds there has been an instability of funding for many areas of research. While recognizing that priorities change, it still is essential to maintain continuity of funding for basic research. Societal payoffs and successful scientific careers both require more than single-shot research projects.
4. Sources of support for graduate research training, many of them under direct federal control, have either been disappearing or drastically reduced. Current levels of predoctoral awards from the National Institutes of Health and the Alcohol, Drug Abuse, and Mental Health Administration are less than one-third what they were in 1975; research and teaching assistantships have become scarce, as the levels of research funds have declined, or because of other economic reasons; and although graduate student loans have not been eliminated as the Administration has proposed, publicity surrounding this proposal discouraged many persons from even applying for them.

We cannot stress enough that there needs to be a strong positive sign of support from NSF for the behavioral and social sciences. If these disciplines continue to be perceived as underfunded, they will be perceived as less promising for future researchers.

The NSF Role

The NSF budget preparation process is where strong support should originate. It appears that requests for disproportionately low funding proposals for the behavioral and social sciences did not originate with NSF staff. However, because of the timing of changes in NSF staff, the agency may have been unprepared to resist the proposals. For example, former NSF Director John Slaughter had little or nothing to do with the preparation of the FY 1981 budget and current NSF Director Edward Knapp had little to do with preparation of the FY 1984 budget.

We are concerned that the current search for an Assistant NSF Director for BBS will result in a similar situation in the upcoming budget cycle. We reiterate our request, made in written testimony on March 10, that your Subcommittee monitor closely the selection of the new head of BBS, to assure that a replacement is chosen on the basis of competence rather than political beliefs. Further, we hope that the appointment will be made in a timely manner so that the individual chosen can be involved in the budget cycle at the earliest opportunity. What must be avoided at all costs is yet another fox-in-the-chicken-coop appointment of the sort that has characterized the current Administration's treatment of governmental units whose programs they dislike.

I hope that this letter and the attached data are helpful in establishing the connection between federal funding policies and the status of research personnel in the behavioral and social sciences. I would be happy to provide more detailed information on any of the above points.

We greatly appreciate the concern you have expressed regarding the proposed FY 84 authorization levels for the social and behavioral sciences. Those levels are inequitable relative to other fields, and are not responsive to scientific opportunities, to Congressional directives, or to national needs. Our written testimony develops this position in more detail. I would simply repeat here our belief that FY 1984 authorization and appropriations should be at levels that restore funding to FY 1980 levels, corrected for inflation. This will not only enable these fields to better fulfill their potential by contributing to the national welfare, but will signal the Congress's belief that these fields join with others in having a significant role to play in addressing critical national needs.

Sincerely,

Ala Kraut

Alan G. Kraut, Ph.D.
Deputy Executive Officer for
National Policy Studies

Attachments

AGK:av

Table 1

Doctorate Recipients in Social Sciences (other than Psychology), 1970-1981

Year of Doctorate	Total
1970	2,676
1972	3,331
1974	3,575
1976	3,707
1978	3,410
1980	3,156
1981	3,148

Source: National Research Council, Office of Scientific and Engineering Personnel, Doctorate Records File.

Table 2

Doctorate Recipients in Psychology by Subfield: 1960–1981

Subfield	Year of doctorate											
	1960	1962	1964	1966	1968	1970	1972	1974	1976	1978	1980	1981
Total	772	856	1,013	1,139	1,464	1,890	2,280	2,398	2,883	3,055	3,098	3 357
Clinical	241	281	400	373	465	549	679	771	883	1,061	1,106	1,456
Counseling and guidance	66	60	47	56	106	115	151	201	267	278	299	351
★Developmental and gerontological	22	26	19	43	62	84	135	162	190	208	207	200
★Educational	60	56	37	47	73	86	127	122	124	145	137	180
School	7	9	22	10	25	45	80	89	143	125	176	133
★Experimental	196	187	225	260	295	366	353	354	357	299	307	282
★Comparative[a]	—	15	11	9	17	22	21	23	28	20	8	11
★Physiological[a]	—	25	37	74	96	116	121	118	133	126	108	102
Industrial and personnel	34	36	50	48	46	75	56	80	73	74	66	87
★Personality	11	27	36	36	31	50	51	60	62	41	43	49
★Psychometrics	15	19	22	27	19	18	25	24	27	15	21	27
★Social	80	61	86	106	123	157	183	202	209	204	190	180
Psychology, general	27	15	13	28	70	122	133	250	218	299	210	283
Psychology, other	13	8	6	15	22	85	157	142	169	160	220	216
Total, Research Subfields*	384	435	475	611	713	901	1016	1065	1130	1058	1021	1031

Note. Source: National Research Council, Office of Scientific and Engineering Personnel, Doctorate Records File.
[a] Fields not added to specialties list until 1962.

Taken, with adaptations, from Syverson, P.D. Two decades of doctorates in psychology: A comparison with national trends. American Psychologist, 1982, 37, 1203-1212.

Table 3

Comparison of Full-time Doctoral Enrollments in U.S. Graduate Departments of Psychology: 1974-75 vs. 1979-80

Doctoral Program Areas	First Year Doctoral Enrollment				Total Doctoral Enrollment			
	# of Departments Reporting	Number of FT Students		Percent Change	# of Departments Reporting	Number of FT Students		Percent Change
		1974-75	1979-80			1974-75	1979-80	
Clinical	93	1,036	1,109	+ 7.0%	90	4,400	4,930	+ 12.0%
Cognitive	33	92	86	- 6.5%	32	423	414	- 2.1%
Community	5	17	18	+ 5.9%	5	59	94	+ 59.3%
Counseling	41	442	388	- 12.2%	41	1,299	1,547	+ 19.1%
Developmental	60	266	227	- 14.7%	58	1,080	1,022	- 5.4%
Educational	31	253	172	- 32.0%	30	717	624	- 13.0%
Experimental	87	392	270	- 31.1%	84	1,672	1,367	- 18.2%
Industrial/Organizational	26	132	125	- 5.3%	25	462	482	+ 4.3%
Physiological and/or Comparative	50	201	128	- 36.3%	45	735	613	- 16.6%
Psychometrics and/or Quantitative	25	80	53	- 33.8%	25	239	211	- 11.7%
School	30	138	171	+ 23.7%	32	555	803	+ 44.7%
Social and/or Personality	66	282	233	- 17.4%	60	1,136	996	- 12.3%
Other programs not listed above	60	326	342	+ 4.9%	38	710	1,028	+ 44.8%
All Programs in Department*	186	4,191	3,558	- 15.1%	185	14,398	15,292	+ 6.2%

* Since several departments reported the total number of full-time students enrolled and did not break down this total by program area, the number of students reported in this row is greater than the sum in each column.

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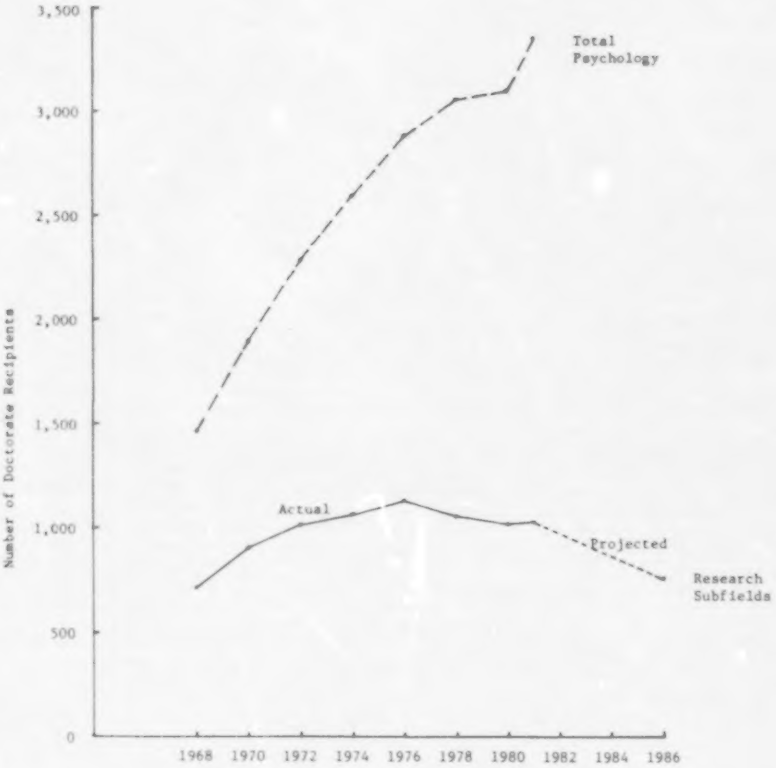

Figure 1. Doctorate production in psychology, 1968 to 1981 (actual) and projected to 1986 for research subfields. Source: National Research Council. Summary Report 1981 Doctorate Recipients from United States Universities. Washington, D.C.: National Academy of Sciences, 1982. Also prior annual reports.

American
Psychological
Association

March 21, 1983

Honorable Doug Walgren
Chair, Subcommittee on Science,
  Research and Technology
U. S. House of Representatives
Washington, D. C. 20515

Dear Chairman Walgren:

Attached is a statement concerning the relationship of behavioral and social science research to productivity as well as an assessment of the adequacy of recent National Science Foundation (NSF) budgets for these fields to address national needs on this issue. The statement includes a chart of recent budget requests and final budgets for NSF's Biological, Behavioral, and Social Sciences (BBS) directorate, plus a number of specific examples of the ways in which behavioral and social science research contributes to productivity.

This statement is provided in response to your request during our conversation of March 18. Please let me know if further information is needed.

Sincerely,

Alan G Kraut (sm)

Alan G. Kraut, Ph.D.
Deputy Executive Officer for
  National Policy Studies

AGK:ri

Enclosures

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The Importance of "The Human Factor" in Economic Productivity and Innovation

Improved productivity is generally assumed to be essential to economic recovery. Productivity is typically defined as the output of goods and services produced by the input of a combination of such resources as capital investment, materials, and labor. Currently, there is great emphasis being placed on developing innovative technological inputs as a key element in improving our nation's productivity. There has not been a commensurate effort to improve the human inputs associated with productivity. Yet the need for innovation in this area is widely recognized.

The House Science, Research and Technology (SRT) Subcommittee in its recent report on "The Human Factor in Innovation and Productivity" found the following to be true:

> Finding I. Historically, the importance of the human factor to innovation and productivity improvement has been underestimated. As a result, it has not been carefully studied and is not well understood. What is known is that organizations in Japan, Scandinavia, and the United States which are demonstrating a sensitivity to the interaction between individuals, both vertically and horizontally in the organization, are realizing reduced turnover, absenteeism, and grievances from employees. These organizations, generally, are also remaining competitive and exhibiting healthy productivity performance in a troubled world economy (p.3).

The processes of using, maintaining, creating, or deploying new technologies are not merely mechanistic nor purely economic. As Brian Usilaner of the U. S. General Accounting Office put it in his testimony before the Subcommittee in September of 1981:

> To put it bluntly, capital and technology by themselves produce nothing. A machine, a process, or a system may be ever so brilliantly contrived, but it is no more effective than the people operating and managing it want it to be or know how to make it (Subcommittee Report, p. 20).

The federal government has a leading role in supporting basic research that leads to innovation. This policy has been adopted by the current Administration, which believes that, in most instances, support of basic research is the most legitimate role for the federal government on the R&D spectrum of activities. However, the Administration has been consistent in its efforts to downgrade research support in the behavioral and social

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sciences, starting with its FY 82 Budget Request which proposed low budget requests for FY 82 and rescissions for 1981. These proposals were accompanied by the assertion that many of the behavioral and social science programs "are considered to be of lesser immediate priority in overall NSF research support" (p. 42, NSF Budget in Brief, March 1981).

The President's FY 84 Budget Request for General Science, Space and Technology contains the following statement: "The principal mission of NSF [the National Science Foundation] is to support basic research in all science and engineering fields." Yet the same budget proposal repeatedly emphasizes investment in the physical sciences and engineering as a means of achieving or maintaining U.S. leadership in such areas as defense and high-technology-dependent industry.

This deemphasis of the non-physical sciences is reflected in the FY 84 budget requests for NSF's behavioral and social science programs. While the agency's budget as a whole is targeted for an increase of 18 percent, the behavioral and social sciences have been targeted for much smaller gains, some as low as 2.7 percent (psychobiology) and 4.7 percent (social and developmental psychology).

The disparately low FY 84 budget request for these sciences is particularly damaging because NSF funding in those sciences has decreased steadily since FY 1980 in terms of real dollars. (See Attachment I for actual figures). For example, the Behavioral and Neural Sciences budget was $36.8 million in FY 80, declined to $29.2 million in FY 82 and has been only partially restored to $33.8 million in FY 83. Virtually all behavioral and social science programs have experienced this funding pattern. In contrast, biology programs within BBS have increased steadily from $111.8 million in FY 80 to $131.2 million in FY 83.

Equally disturbing is the pattern of budget requests in the past four years. These budget requests constitute a pattern of neglect that overlooks the value and contribution of these sciences in improving the industrial and economic productivity of this nation. That contribution is described briefly below.

Examples of Contributions of Behavioral and Social Science Research to Productivity

The overall place of, and contributions by, behavioral and social science research in the U.S. economy is well established:

> Past investments in the social and behavioral sciences have led to and improved technologies of considerable dollar value. Multi-million dollar industries have emerged in the United States from findngs and discoveries traceable to the social and behavioral sciences. A profit-oriented private economy adapts and applies these products, just as it purchases electronics or medicines which started as physial or biological science

> discoveries. Important enterprises are now built around economic forecasting, demographic projections, political polling and survey research, standardised educational, aptitude, and intelligence testing, personnel selection and management counseling, languge instruction, psychotherapy, cost-benefit analysis, human engineering system design, consumer reseach, marketing analysis, symbols and image design, and information dissemination. Whole industries and professions such as advertising, public relations, and mass media audience measurement services, draw continuously on information, techniques and measures developed in social and behavioral research. Technologies are also exported (e.g., Gallup International). They also attract foreign investments as thousands of students come from abroad for advanced training in econometrics, linguistics, demography, survey methodology, psychometric testing, management science, etc. (Larsen, 1981, p. 8)

Specific examples of contributions include the following:

o Personnel selection and assessment: It has been estimated that approximately $15 billion could be saved yearly by the federal government alone if it used improved employee selection procedures. The estimated savings for the economy as a whole is about $80 billion yearly, or about 3 percent of gross national product.

o Survey research: A sizable industry itself (estimated to have been $4 billion in 1978), surveys are increasingly used by business (for crucial investment decisions), by government (to predict future revenue, among other uses), and by innovators (to assess the market potential of new products and services) (Tornatzky *et al*., 1982).

o Human factors research: Long used in the design of industrial production lines (one intervention by human factors reserchers cut total assembly time from 76 to 28 minutes), it has also been extensively used in standardized highway signs, in the design of both military and civilian aircraft, and in the design of countless products involving the adaptation to human abilities and dimensions (e.g., furniture, tools, etc.). As a result of the Three-Mile Island incident, which subsequent study showed to be caused more by human factors design shortcomings than by equipment failures, the Nuclear Regulatory Commission enlisted the aid of the Human Factors Society in a major study of the design of nuclear power equipment.

o Organizational design: A number of different organizational factors, such as shared decision-making, decentralization, goal-setting, and tying employee compensation (in part) to overall firm performance have been shown time and time again to be related to worker productivity, morale, and quality of work life -- factors that have sizable economic effects. Such changes in design have saved firms millions of dollars and have saved some from economic extinction. Organizational design also affects such things as workplace safety and accident reduction, which was shown to be improved in some studies using behavioral intervention by as much as 60 percent; worker absenteeism and turnover, which unaddressed can cost firms sizable amounts; and alcohol and drug abuse, whose effects on productivity alone is estimated to be about $30 billion a year.

The Need for Further Social and Behavioral Research on Productivity

Despite these examples, it was the consensus of most witnesses testifying before the Subcommittee in the September 1981 hearings that there is an overall lack of reliable, systematic research on the impact of human factors on innovation and productivity. The Subcommittee's report states:

> Finding VI. There is a need for research by social scientists and economists to better understand the workplace and the relationship of human factors to innovation and productivity. The impact of technology on the workers, and the factors necessary to realize the effective implementation of technology in the workplace need to be explored. Problem-oriented, as well as discipline-oriented research should be encouraged (p. 9).

The Need for Increased Federal Funding for Social and Behavioral Research

In view of the drastic reduction in funds available for social and behavioral research, particularly from the National Science Foundation, the Subcommittee's Report raises to "questions as to [NSF's] commitment to social and behavioral sciences, as opposed to the physical sciences" (p. 33). Chairman Doug Walgren views the situation as being "of utmost concern given the impact of human factors in U.S. innovation and productivity" (p. 34).

Therefore, the Subcommittee concluded, in one of its major recommendations:

> Congress should provide funds for research on the interaction between human factors and innovation and productivity. National Science Foundation programs, in particular the social sciences, should be emphasized (p. 10).

References

Larsen, O. Need for continuing support for social sciences. ASA Footnotes, March 1981, p. 8.

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Tornatzky, L. G., Solomon, T., Bikson, T., Cole, R., Friedman, L., Hage, J., Kiesler, C. A., Larsen, O., Menzel, D., Nelson, S. D., Sechrest, L., Stokes, D., and Zaltman, G. Contributions of social science to innovation and productivity. *American Psychologist*, 1982, *37*, 737-746.

ATTACHMENT I

NATIONAL SCIENCE FOUNDATION BUDGET FY 80 - FY 84

(in millions of dollars)

	FY 80	FY 81		FY 82		FY 83		FY 84
	Actual	Request	Actual	Request[a]	Actual	Request	Planned	Request
NSF RESEARCH AND RELATED ACTIVITIES (Total)	893.1	1,056.8	946.7	1,020.1	974.6	1,055.6	1,064.0	1,250.7
Biological, Behavioral and Social Sciences (Total)	185.7	182.0	185.6	172.0	176.0	186.7	190.2	223.6
Biology	111.8	115.5	119.3	126.5	122.1	130.2	131.2	156.3
Behavioral and Neural Sciences								
- Neuroscience	15.7	22.1	21.0	18.2	20.4	21.8	21.4	24.4
- Cognitive and Behavioral Science	14.5	9.1	8.3	6.0	5.9	6.1	6.6	7.2
- Anthropology	6.6	7.6	6.0	5.0	5.5	5.6	5.8	6.3
Subtotal, Behavioral/Neural Sciences	36.8	38.7	35.3	29.2	31.7	33.5	33.8	37.9
Social and Economic Science								
- Economics and Geography	13.8	15.8	10.6	4.2	7.0	7.1	7.9	10.1
- Social Measurement and Analysis	10.4	12.0	8.0	3.5	6.0	6.1	6.8	7.5

[a] These figures are taken from the Reagan Administration's revised FY 82 Budget Request, submitted March 1981.

	FY 80	FY 81		FY 82		FY 83		FY 84
	Actual	Request	Actual	Request	Actual	Request	Planned	Request
Social and Economic Science (cont.)								
- Political and Policy Sciences	7.2	6.6	6.5	2.5	4.5	4.7	3.1	5.7
Subtotal, Social and Economic Science	31.4	34.4	25.1	10.1	17.6	17.8	19.8	23.3
Information Science	5.6	6.6	6.0	6.2	5.2	5.2	5.4	6.1

[Questions for the record on subjects covered by today's hearing, with the formal responses of the National Science Foundation:]

Information Science and Technology

QUESTION: The Committee Report Authorizing Appropriations to NSF for FY 83 stated, "it is the Committee's view that the Foundation allocate up to $6.5 million to the Division of Information Science and Technology". What was the rationale for allocating approximately $1 million less than the Committee directed?

ANSWER: The FY 1983 appropriation for the Foundation did not provide sufficient funds to meet all Congressional recommendations and directions. Careful consideration was given to the competing requirements of a wide variety of efforts, to all Congressional guidance, to scientific needs and opportunities, and to achieving a balanced program within the total available funds. Additional amounts were allocated not only to information science and technology, but also, for example, to the behavioral and social sciences and international cooperative activities. The final FY 1983 program is, we believe, responsive, well-balanced and sound within the context of our FY 1983 appropriations total.

QUESTION: What value do you place on the contribution of Information Science and Technology in addressing productivity and economic concerns? Computer Research is proposed to receive in FY 1984 a 19% increase over FY 1983, and Computer Engineering a 25% increase -- why does Information Science receive only a 13% increase (bringing the funding level back to that of FY 1981)? Why is the large increase proposed for Computer Engineering, when this field is proving so lucrative in the private sector?

ANSWER: There has been widespread discussion, in general terms, about the potential contributions to increased productivity and economic growth attending the Nation's movement into the "information and communications age." Recently, the interrelations among the fields of information science, computer science and computer engineering have been examined both within the Foundation and by the National Science Board (NSB). A January, 1983 workshop sponsored by NSF brought together leaders in these fields to discuss the state-of-the-art and areas requiring additional research. In March of this year, the NSB was briefed on these fields as part of its responsibilities for policy direction.

In all three areas -- information science and technology, computer science and computer engineering -- the Foundation emphasizes support of long-term fundamental research. The aim of research and development supported by industry, say in computer engineering, is typically oriented more towards immediate payoff and proprietary benefit. This is in contrast to NSF-supported research which provides the knowledge from which an industry and the Nation as a whole may be able to benefit.

The 13% increment proposed for the information science subactivity reflects the decision to place higher priority on meeting needs for research instrumentation and plant biology, and will allow real growth in this area of science.

QUESTION: What direction has the staffing and funding pattern of the Information Science Division taken since it became a Division within BBS?

ANSWER: Information Science and Technology became a subactivity within BBS in FY 1981. Funding for IST in FY 1981 was $5.9 million; in FY 1983 it is estimated to be $5.4 million; the FY 1984 request is $6.1 million. Staffing for IST has decreased from 14 full-time positions in FY 1981 to 9.8 full-time equivalents in FY 1983.

QUESTION: Would NSF be able to develop a more effective and comprehensive program if the Information Science, Computer Science, and Computer Engineering Divisions (now located in three directorates — BBS, MPS, and Engineering) were brought together in a new directorate where adequate and coordinated management attention could be given to all programs? What mechanisms are used to coordinate the activities at the present time?

ANSWER: There is a strong and definite linkage between the information sciences and other research supported in BBS. Special ties exist with the cognitive, linguistic and economic sciences, and the current administrative arrangements strongly encourage cooperation and planning. Coordination with the mentioned computer support efforts is excellent, with programs in the various directorates jointly funding proposals, taking part in each others' advisory committee meetings, developing and participating in special workshops, and in preparing special presentations such as that for the March 1983 meeting of the National Science Board. The present arrangement has allowed the Information Science and Technology, Computer Science and Computer Engineering programs to draw and build upon the cognate research taking place in three directorates. It has the further advantage of facilitating a flexible approach to support of a very rapidly changing field of science.

QUESTION: Does Policy Research and Analysis (STIA) support research in the area of information policy? How is that program coordinated with the priorities for Information Science (BBS), Computer Science (MPS), and Computer Engineering (ENG)?

ANSWER: The Policy Research and Analysis (PRA) division primarily has supported policy research in the area of computer technology. PRA limits itself to policy research and analysis, while IST supports the fundamental research on economic and societal impact of information science and technology which is essential to the policy analysis process. Computer engineering (ENG) is directed at broadening the understanding of principles of design and construction of computers, while computer research supported through the MPS directorate tends to be more software oriented. The complementarity of all of the Foundation's computer-related efforts is ensured through the close and continuing contacts between their respective staffs. For example, PRA is now proposing a new initiative covering policy issues involving computers, communications and information. One part of this effort was a workshop held in Dedham, Massachusetts on March 20-23 of this year at which PRA and IST program managers were represented.

QUESTION: Last year we received a letter signed by about 30 distinguished scientists including Nobel winners in Physics, Biochemistry, and Economics urging increased support for Information Science at NSF. Why do you feel this unique and new discipline can be nurtured at the proposed funding level, especially when the Division received less support in FY 1982 and FY 1983 than in FY 1981?

ANSWER: The FY 1983 Current Plan for information science research increases support over FY 1982 and brings it to $5.4 million; an additional increase of about 13% in FY 1984 results in a total of $6.1 million for this area. This latter requested increase provides for growth and would bring FY 1984 above the FY 1981 level. Information Science and Technology is an emerging field of research and this level of funding would permit NSF to fund about 50% of proposals received by it. The success ratio in other BBS programs -- some of which are also in rapidly advancing high-growth fields -- by comparison, is of the order of 20-30%.

Women and Minorities

QUESTION: In a year when the NSF budget has had substantial increases in its proposed budget for 1984, there has been no increase in the funding of programs for minorities, or in the one program, the Visiting Professorships for women scientists. Why have these programs not received additional support?

ANSWER: In FY 1982, the Foundation found that the funds budgeted for the Minority Research Initiation program exceeded the amount requested by the quality proposals received. In evaluating the Minority Research Initiation program it was decided to hold the program funds at the level of $2,000,000 for the immediate future until it was determined that a need for increased funding was justified.

Also in FY 1982, the first year of the Research Improvement in Minority Institutions, the original budgeted figure was $500,000. This was increased to an obligation figure of $907,826 in FY 1982. Since $2,000,000 was the anticipated ceiling for this program, the Foundation has held this program at level funding for the immediate future. As there are a limited number of eligible schools (about 30). this figure may remain constant.

The program for Visiting Professorships for Women (VPW) shows a 200% increase from FY 1982 to FY 1983. The high quality of proposals in FY 1982 resulted in additional funds being awarded — an increase of $448,000 over the allocated $500,000. In FY 1983, the allocation is $1,500,000 and it was decided to maintain this level in FY 1984 to maintain the high quality of the program.

All programs are reviewed each year before and during the preparation of the annual budget requests and determinations are made based on the needs of the program and the priorities of the Foundation.

QUESTION: Since funds are present in the 1984 NSF budget for various program additions, why was there no funding for the National Research Opportunity Grants, or a similar research initiation program for women?

ANSWER: There were no program additions. Funds have been used to expand existing programs within the research directorates. It is anticipated that these expanded research programs will prove as equally beneficial to women as to men. The program of Presidential Young Investigators will be funded out of the expanded research programs, and the Foundation anticipates that a sizable proportion of the 200 awards will be made to women. It is not the intent of the Foundation to create new set aside programs but rather to expand opportunities for women within the existing research programs.

QUESTION: At present, NSF has no program to encourage women to choose technical careers, or to help them to return to such careers and fully utilize their abilities after a career break. Such programs have existed at NSF in the past, and they were evaluated, and found to be highly effective. The reentry programs, for example, have been shown to return more in tax dollar increases than they cost. In view of the continuing need for such efforts, and the known effectiveness of programs in this area:

1) Why does NSF not have program proposals to increase the participation of women in science in its 1984 budget?

2) What planning is now underway to develop such programs for future years?

ANSWER: While there are no specific proposals in the 1984 budget request for reentry programs for women, there are opportunities within existing programs for women to utilize their scientific training after a career break, e.g. Presidential Young Investigators, Undergraduate College Research Support, Visiting Professorships for Women, etc. It is envisioned that as program officers become more familiar with their role of responsibility for the full range of scientific needs in their disciplinary area, a greater sensitivity to issues such as the reentry problems of women scientists will be developed and provision of opportunities will be strengthened.

The Director is currently working with the Committee on Equal Opportunities in Science and Technology to review NSF activities for minorities and women and to, where appropriate, recommend new efforts and/or strengthen existing ones. Reentry programs will be discussed as a part of this review.

QUESTION: NSF funding for programs for women reached its highest yearly amount in 1981, when slightly over 2 million dollars went to programs to increase the participation of women in science. The 1984 budget proposal of 1.5 million is less than 75% of the 1981 amount; the actual decrease is even greater when inflation is considered. Why is NSF decreasing its support for effort to increase the utilization of the scientific talents of women, at a time when the country's needs for trained technical talent is increasing?

ANSWER: In FY 1981, approximately $2 million of Science and Engineering Education funds went to targeted programs to increase the participation of women in science. The programs funded here provided educational enrichment for young women through career awareness workshops and educational upgrading for women with baccalaureate degrees in science who were unemployed or underemployed. Subsequently, Science and Engineering Education funds were cut back; $15 million were provided for the Graduate Research Fellowships and all other programs were terminated.

In FY 1982, the Foundation established the Visiting Professorships for Women at $500,000 (this was actually increased to $948,000 because of the exceptional high quality of the proposals) and has subsequently been increased to $1,500,000 for FY 1983 and FY 1984. This represents an increase over 1982 of 58%.

NSF is not decreasing its support for efforts to increase the utilization of the scientific talents of women. Rather, it is anticipated that by having the research directorates assume greater responsibility for the health of all science, they will become more aware of, and responsive to, the needs of women scientists.

QUESTION: At present, NSF has no program of research initiation targeted towards women, though such a program was included in the congressional recommendations in the 1981 NSF authorization, and have been supported by the recommendations of subsequent advisory groups, such as the Committee on Equal Opportunities in Science and Technology. What plans do you have to implement these recommendations in subsequent budgets?

ANSWER: The Director is working with the Committee on Equal Opportunities in Science and Technology to review existing minority and women's programs. Where appropriate, increased funding or new activities will be recommended to provide additional and/or strengthened opportunities for minorities and women in science and technology.

QUESTION: The NSF Visiting Professorships for Women in Science and Engineering is entering its second year. The first year was highly successful, with well over 100 highly qualified applicants, despite the very short application period. Much of the success of the program to date has been due to the excellent administration of the program by the program coordinator during its first year. Since the program requires that an applicant find a university where she can visit, which can provide both the research and the opportunities for teaching and involvement with students which are part of the program, it is more complicated to administer than the usual grant program, and requires specialized knowledge of the needs of women in science and experience with this type of program.

In view of these considerations, the proposal to decentralize the administration of this program among the various research directorates raises a number of questions.

1) How many program managers are going to be involved in handling the program? In view of the small amount of money available for this program, isn't distributing it over the directorates bound to result in the program managers responsible having virtually no experience with it? If each of a number of program managers is responsible for one or two awards, at most (which would seem to be implied by distribution), how are they all going to be trained? How are common standards going to be maintained in the administration of the program? What kind of tracking will be done to insure that the award process conforms to the program specifications? How much will this process increase the overhead costs associated with the program? (On the face of it, so much duplication of administration over so few awards would appear very inefficient; either the quality of the administration is going to be allowed to decrease, or the costs will have to increase greatly, it would appear).

2) If these assumptions about multiple program managers are not correct, then what does distributing the program over the directorates mean? Who will be in charge, and what kind of authority will they have?

3) NSF at present devotes only a small portion of its research money to supporting research by women scientists (Current estimates are that about 11% of awards go to women; it is likely that the dollar amounts going to women are substantially less than this.) Is there not a danger that if this program is added in as part of the regular grant program, the program managers will view this as "the money for women" and decrease even further the amount of support for women scientists? (At present, since it is handled as a separate program with special features, it is not viewed as a replacement for support of women under the usual grants process.)

ANSWER: The details of the proposed distribution of management responsibility for the Visiting Professorships for Women program as for the others affected, have not yet been determined. However, it seems likely that for FY 1984 the program will be administered much as in FY 1982. That is, the program officer in STIA will receive proposals, arrange reviews (with the assistance of research program officers), and recommend final disposition of proposals. The $0.5M from the research directorates projected to be spent on VPW will be combined with STIA's $1.0M and administered as a whole.

During this transition year the STIA program officer will work closely with research program officers in planning for FY 1985. For 1985 it is anticipated that decision responsibility will be shared by the research directorates and the STIA program officer who will serve as a resource and provide overall coordination in terms of tracking expenditures and answering inquiries.

It is envisioned that funds will be delineated specifically for VPW activities. Directorates would be expected to continue to consider individual research support grants as they do now and thereby should show an increase in support for women, not a decrease.

QUESTION: The perception in many quarters is that Reagan Administration is hostile to efforts to increase the utilization of the talents of women in non-traditional professional areas such as science and engineering. The systematic efforts to eliminate any funding for projects that would contribute to increasing the educational opportunities for girls and young women in mathematics and science at the Department of Education has contributed to this public perception. NSF, which used to support research which has been important in developing methods to increase the mathematical and science skills of young women through programs in the science education directorate, no longer supports such research. Thus, there has been a virtual elimination of federal support for the research and development efforts needed if more women are going to receive the early education needed so that they can consider careers in science and engineering. In view of these considerations:

1) Has NSF surveyed the impact of this very substantial decrease in funding on educational needs in this area, especially as they affect women?

2) If so, what conclusions have you come to, and what are your plans for dealing with needs which are now unmet? If such a study has not been done, what have you done to meet NSF's responsibilities towards developing the scientific human resource base, where women's talents, and those of minorities, are currently the largest underutilized talent pool?

3) What specific proposals does NSF plan in its current initiatives in the pre-college area to improve educational opportunities for girls in science and mathematics?

ANSWER: NSF has not conducted any surveys of recent funding patterns for the support of educational programs in science for women. We have continued the Graduate Fellowship Program, the Visiting Professorships for Women, the Minority Research Initiation Program and the Research Improvement in Minority Institutions Programs, all of which are specifically aimed at developing the scientific human resource base. We have also expanded the support for graduate students and postdoctorals on research grants.

Our precollege activities for FY 1983 and FY 1984 are still in the formulation stages. Whatever plan is finally adopted will be sensitive, to the extent appropriate, to the special needs of all the segments of the precollege science student population.

QUESTION: The perception that the Reagan administration is hostile to the utilization of the talents of women in science and engineering is likely to have been strongly reinforced within the scientific community by recent events at NSF, especially by the forced resignation of Dr. Eloise Clark, the only woman Assistant Director. If it is not, in fact, the policy of this administration, as currently implemented at NSF, to perpetuate barriers to the participation of women in science, what steps is NSF taking to indicate to the scientific community that its intentions are not what they appear to be? Why was such an unnecessary signal sent in the first place if the current administration is not, at best, indifferent to the question of effective utilization of women in science?

ANSWER: Dr. Clark, the Assistant Director for Biological, Behavioral and Social Sciences, like the Assistant Directors for Astronomical, Atmospheric, Earth, and Ocean Sciences, and Mathematical and Physical Sciences, and the Deputy Director of the NSF, is a Presidential appointee serving at the pleasure of the chief executive. Consonant with the decision to establish a new management team at the Foundation, all the incumbents of the aforementioned positions were asked to step aside. The Director and the National Science Board are making every effort to include highly qualified men and women as candidates for the President to consider in filling these jobs.

Discussion of Proposed Management Plan

Many of the questions which follow center around the management system proposed by the Director of the National Science Foundation in a memorandum dated January 12, 1983, to the NSF Executive Council. A few general comments about the proposal are provided here to place both the questions and answers in context.

The proposal described in the January 12 memo was distributed to serve as the basis for discussions among the senior management staff of the Foundation. It was not intended as a final document.

An important point to be noted is that what is proposed here is an examination of the distribution of management responsibility for several of the Foundation's activities. A reorganization is not proposed and the Director in his March 10, 1983 statement before the House Subcommittee on Science, Research and Technology said, "I project that no organizational changes will be required in the Foundation to accommodate these shifts in responsibilities." There may be some limited number of individual personnel adjustments but these should be at a minimum.

It is far too early to judge exactly how all programs and activities will be affected. Many details need to be thoroughly discussed and alternatives explored. The Director has assigned responsibility for developing an implementation proposal to the Assistant Directors operating as a group. They are now involved in that endeavor.

The proposals for shifting management responsibility are offered with the goal of setting in place that management system which will allow the National Science Foundation to fully realize the opportunities represented in our budget request.

QUESTION: What will be the precise role of STIA program managers for the programs proposed to be shifted now that research directorate personnel are to be given "sole" responsibility for receiving, evaluating, and decisionmaking on all proposals..." according to the wording of the Director's January 12 memo?

ANSWER: The precise roles of STIA and research directorate program managers have yet to be determined in any detail. It is likely that the distribution of management responsibility will vary from program to program. The steering group appointed by the Director will examine alternatives and recommend an appropriate distribution of responsibility for each area.

QUESTION: Will the STIA personnel level be cut back as a result of the new management scheme?

ANSWER: It is too early to speculate on the personnel consequences of any shift in management responsibility which might be adopted after studying the various options and their implications.

QUESTION: How can STIA coordinate these programs if it no longer has responsibility for funding, priority-setting and evaluation?

ANSWER: There are many types of "coordination" possible. These different modes are part of the overall discussions on distribution of management responsibility. One of the definitions of coordinate is to "cause to act together in a smooth concerted way." This would be one of the criteria used in choosing appropriate coordination mechanisms for the activities in question.

QUESTION: Common-sense holds that personnel will have to be added to the research directorates to enable them to fulfill their new responsibilities for program management for the proposed shifted "special programs." But the responsibilities of the STIA personnel will be cut back, merely to coordination. Does not this reorganization, in effect, mean having to add another layer of personnel and red tape to program management for these former STIA "special programs."

ANSWER: We certainly hope not. Although it is too early to be specific, every effort will be made to adopt the most efficient and appropriate mechanism for coordination.

QUESTION: At one point in his January 12 memo, the Director says that peer reviews and funding decisions will be made on the basis of the appropriateness of the case involved. Doesn't this mean that the research directorates will be using the same kind of procedures STIA used to evaluate and funds these programs? If so, what are the merit of shifting these "special programs" to the research directorates?

ANSWER: The issue here is not one of procedure since these are both standard throughout the Foundation, yet flexible enough to allow "appropriateness" for individual cases. The merit of the proposed shift is to ensure both that the quality of science research supported is of the highest quality possible and that a holistic approach is taken by program managers in their support of projects. These changes are intended to enhance the incorporation of concern about and planning for women, minorities, and international activities into all the Foundation's programs and to further the goals of broadening the attention of the entire Foundation to the overall health of science and technology.

QUESTION: Some of the programs to be shifted have not received enthusiastic support from the National Science Board in the past since the Board has announced, more than once, that NSF's fundamental mission is the support of basic research and graduate education. Won't these "special programs" just get lost in the shuffle once they are decentralized?

ANSWER: No. On the contrary, it is envisioned that they would become an integral part of all program officers' responsibilities.

QUESTION: The Director in his Jan. 12 memo called the programs to be shifted "special programs." Aren't they special in the sense that some of them serve equity purposes and are compensatory in nature, far from the mainstream of NSF's goals. How will these programs be able to compete equally with proposals for research in the research directorates?

ANSWER: These programs have perhaps been seen by some in the past as compensatory or serving equity purposes. They are not, and should not be perceived as "far from the mainstream of NSF's goals." Removal of this perception is a driving force in proposing a change in the distribution of management responsibility in the Foundation.

Interaction with program officers and increased familiarity with Foundation procedures is intended to remove the barriers, perceived or real, to competition for funding in the research directorates.

QUESTION: In his memo of Jan 12, the Director said that shifting these special programs to the research directorates would broaden the horizons for them. How will this shift effect such a goal? Won't research directorate personnel give more attention to the support of basic research with less attention to these special concerns?

ANSWER: It is envisioned that all program managers will be responsible for the whole range of needs and issues which bear on the health of science and technology as represented in their particular discipline. The activities being proposed for shift are basic research activities and will be part of the spectrum of basic research supported through a given program.

QUESTION: The FY 1984 NSF budget justification to the Congress (p.20) indicates that research directorates will be given complete funding authority over 6 programs formerly handled by STIA and some funding authority over 2 other programs. The total amount of funding to be shifted constitutes $28.1 million. If the research directorates do not find proposals to be of acceptable quality, will the research directorates automatically spend the former STIA funds for research?

ANSWER: Three of the six programs to which reference is made are new and are being established as jointly managed. They are not "programs formerly handled by STIA." These are the U.S. India Joint Program ($2.0M), the Presidential Young Investigators Research Awards ($6.0M), and the Undergraduate College Research Support program ($3.0M). The other three (Experimental Program to Stimulate Competitive Research ($2.5M), NSF Planning and Evaluation ($2.0M), and the Waterman Award ($0.2M) are shown in STIA for display convenience and will be administered as before with STIA providing accounting support and coordination across the Foundation as required. These programs are all research programs for which it is anticipated that meritorious requests will exceed the number which funding levels will accommodate.

QUESTION: In the past STIA has not been considered one of the strongest NSF directorates, and today its proposed budget of $36.8 million constitutes only 3% of the total request for research and related activities. How does NSF expect such a weak directorate as STIA to be able to "coordinate" programs whose responsibility is being shifted to the research directorates?

ANSWER: The exact distribution of management responsibility is expected to vary from program to program. The different possible arrangements form the core of the current discussions. The arrangements chosen for individual programs will build on the strengths of both STIA and the research directorates in order to assure the most appropriate distribution in each case.

QUESTION: How much in funding will support for basic science suffer or gain from the proposed reorganization?

ANSWER: The proposed shift of management responsibility will have no impact on the support for basic research proposed in the FY 1984 budget request.

QUESTION: Is it not true that these so-called "special programs" were put in STIA in the first place because they are so different from programs for the support of basic and applied research that they could not compete with such programs on an equal basis?

ANSWER: It has certainly been a perception that the programs designed for special groups are "different" from the regular research programs of the Foundation. We plan to explore alternatives to this separateness and to choose the organizational arrangement which allows the Foundation to most effectively carry out its responsibilities for the overall health of science.

QUESTION: Some observers allege that in the past, funding eroded for certain NSF programs that were once in separate units, once the program's administration was decentralized and funding spread over several directorates. Didn't this happen with applied research, which once was in a separate directorate? What does this imply for the future identity of the separate "special programs" in STIA proposed to be shifted?

ANSWER: Funding for applied research proposals has been fully integrated throughout the research directorates of the Foundation. A tracking system has been put in place and expenditures can be tracked proposal-by-proposal and directorate-by-directorate. In FY 1982 more than $55 million was provided for the support of applied research activities. There were significant numbers of projects and expenditures in all of the research directorates. This implies that relocating management responsibility for "special programs" is feasible without loss of identity and integrity.

QUESTION: Many of the programs proposed to be shifted from STIA into the research directorates appear to have been congressionally-initiated. NSF did not initiate most of these, the Board appears to have considered them tangential to the NSF missions, and the Congress has often raised funding for them above the level requested. Is the intent of decentralizing these programs to see that they disappear--like the RANN program did?

ANSWER: By distributing management responsibility for these activities, their present compartmentalization would be ended, thus ensuring that they are not perceived as tangential to NSF missions. Rather than disappearing, it is envisioned that they would become an integral part of the entire spectrum of research support for which program officers are responsible.

QUESTION: Because the programs to be shifted were congressionally initiated, and OMB has kept funding very low for them, the Congress has often set floors on funding for the programs to insure their maintenance, for instance science education, some programs for women and minorities, etc. How can Congress set floors on these programs and insure oversight of them if funding is to be dispersed throughout several different research directorates?

ANSWER: If the Congress feels it necessary to set floors on programs, it is the responsibility of the National Science Foundation to meet them and it will do so.

QUESTION: What role did the National Science Board play in developing this new management philosophy and reorganization plan?

ANSWER: The Director has discussed this proposed shift in the distribution of management with not only the National Science Board, but also the Office of Science and Technology Policy, the Office of Management and Budget, three previous NSF Directors, the Chairperson of the NSF Committee on Equal Opportunities in Science and Technology, the Women's Subcommittee of that Committee, the Steering Committee of the Director's Advisory Council, and with the Assistant Directors of the Foundation.

QUESTION: Just how much more will this proposed reorganization cost NSF in terms of additional personnel and other costs?

ANSWER: It is premature at this time to speculate on what effects, if any, this proposed shift in the distribution of management responsibility will have on personnel or other costs.

QUESTION: The Director said in his Jan. 12 memo that the programs to be shifted "typically have not had the resources to have an appreciable impact." Don't others believe that these programs have, indeed, had benefits? How will shifting the programs to the research directorates increase their resources? It seems that just the opposite will occur?

ANSWER: Unquestionably, there have been positive benefits from these programs. The time has come, however, to consider new ways of managing them and of integrating them more effectively into Foundation research activities. To put them in separate budgetary and organizational pockets is to think of them and treat them separately - as if they were not a legitimate, central concern of the Foundation. Some program officers have paid little attention to them; hence, the targeted groups do not learn to deal with the disciplinary program officers. As one might expect, under such circumstances, it is unlikely that research resources will increase above the targeted amounts.

A first step in eliminating this "separateness" will be to blend these programs into the disciplinary research activities so that program officers will have to consider them as part of their primary responsibility. By interacting with program officers, these targeted groups will learn more about their expectations and the expectations of the research communities they represent. This will certainly give them access to a much more substantial support base.

QUESTION: According to the Jan. 12 memo, both funding responsibilities and the determination of priorities for the former STIA "special programs" will be shifted from STIA personnel to the research directorates. Yet STIA personnel will retain responsibility for coordination. How can STIA programs provide effective coordination and oversight for programs whose funds they do not control and priorities they do not set?

ANSWER: The exact nature of the coordination functions to be distributed between STIA and the research directorates has yet to be determined. However, the role of the STIA staff will be significant, particularly in the international area. The leadership they provide will be key in allowing the Foundation to fulfill its commitments under bilateral and other agreements.

QUESTION: If this reorganization means that some bilateral and multilateral international science programs will be cut, which ones will be cut first?

ANSWER: While it is premature to speculate on all of the future impacts which the proposed shift in management responsibility might have, there is no a priori reason to believe that whatever arrangement is chosen will result in reductions or cuts in bilateral and multilateral science programs.

QUESTION: In the Sept. 1982 statement on international science, the Board recommended that "the Director of the Foundation must play a significant role, in collaboration with the Dept. of State and the Executive Office of the President, in the development and implementation of the international science policy of the United States." Doesn't the decentralized reorganization proposal give the Director less, rather than more, control over international science? If not, elaborate on how the Director gains more control.

ANSWER: Whatever final decisions are made with regard to the distribution of management responsibility for the international activities of the Foundation, it will not change the Director's ability or responsibility to exercise appropriate executive control of these activities.

QUESTION: In a Sept. 1982 policy statement on the need to increase NSF international science responsibilities, the National Science Board said "The Foundation, by virtue of its fundamental and broad-based scientific program, should take the initiative, in cooperation with the Department of State and other agencies as appropriate, to bring together potential international partners to accomplish the necessary planning and implementation for international sharing or collaboration in fundamental science and engineering research." However, there is a natural tendency in the research directorates to support domestic science over international science. Doesn't the shift of international responsibilities to the research directorates, therefore, imply that such programs will be minimized in favor of domestic science, thus achieving the opposite of the NSB policy?

Just how will such a decentralization enhance NSF international responsibilities compatible with the NSB policy statement and also allow the maintenance of continuity and meeting of all U.S. international commitments?

ANSWER:

- It should be noted that currently there is significant support for international science outside of the STIA/INT activities. Funds are provided for scientific visits and research activities through SRPS grants, international scientific meetings are supported, and funds are provided for the use of experimental facilities such as CERN.
- The shift to a shared responsibility between STIA and the research directorates implies that the kinds of research supported under international agreements will be more closely linked with the Foundation's other activities.
- The Director has stated that the implementation of a distributed management responsibility system will not impede the Foundation from fulfilling its commitments under bilateral and other agreements.

QUESTION: On p. NSF-20 of the FY 1984 NSF justification, it is indicated that more than one-half of the STIA international program will be shifted to the research directorates. Which programs will be shifted and which will remain with STIA? What criteria are to be used to shift these programs?

ANSWER: STIA will continue to coordinate and manage the Foundation's bilateral agreements; support seminars, workshops, and scientific visits; and facilitate the support of cooperative research projects within NSF. These activities are budgeted at $5.0 million in FY 1984. The discipline-oriented research directorates will manage the research project proposals included under bilateral agreements. In FY 1984, at least $5,900,000 will be provided by the research activities of the Foundation for international cooperative research projects.

QUESTION: Regarding the shifting of international cooperative programs, how can program managers in the research directorates, who will fund international programs and foreign research programs be expected to know as much about foreign science and research capabilities as the STIA program managers who are in constant contact with foreign science communities? If the STIA managers are to transmit information to the research directorate personnel, doesn't this just add a layer of needless red-tape?

ANSWER: The STIA staff will maintain up-to-date awareness of international science and engineering by establishing and maintaining close partnerships with program officers in the "research directorates" as well as with their counterparts in other countries. Under the proposed arrangements, STIA staff will also be expected to maintain current awareness of international protocols, applicable laws, and broad U.S. Government policies and priorities and to keep both the senior management staff and the research program officers fully informed.

QUESTION: The Director proposes shifting funding for many international science programs, including bilateral programs to the research directorates. But it is widely acknowledged that the United States concludes bilateral agreements for political purposes and that the science embodied often will be poor. The Director proposes that the research directorates be given responsibility for "the actual handling, evaluation, and formal decision-making on all proposals involving international science." Yet the proposals for cooperative science will never compete successfully against proposals for domestic research. Just how will we be able to meet our international commitments?

ANSWER: Meeting our international commitments under bilateral agreements does not depend on the distribution of management responsibility. The Director has stated that we will meet international commitments and indeed we hope to expand these opportunities. One of the important outcomes of distributing responsibility between STIA and the research directorates is that programs will be jointly designed. This will enhance the quality of proposals and increase their competitiveness.

QUESTION: On p. 4 of his Jan. 12 memo describing the reorganization, the Director states that, in the future, research directorate personnel will be expected to accompany STIA personnel in arranging international programs. Just how much more will this cost NSF? How will such travel be regulated and who will actually represent NSF? Who will actually travel - program managers; analysts; assistant directors?

ANSWER: The Director's steering group of Assistant Directors will be dealing with operational questions such as these as they develop the detailed implementation plan for the proposed shift in distribution of management responsibility. It is premature to try to answer these questions of detail before the larger, more comprehensive issues have been resolved.

QUESTION: On p. 4 of the Jan. 12 memo, the Director commenting on an expected outcome of the reorganization in the international area, says "out of these various activities would come a genuine interest on the part of NSF staff and some U.S. scientists to participate in new or expanded collaboration with counterparts in the bilateral country." This conclusion seems to overlook the history and reality of years of international programs, which are generally characterized by poor science, in which U.S. scientists do not wish to collaborate. Just how will the proposed reorganization overcome the politics and reality of previous bilateral cooperation?

ANSWER: That there is a perception that the research supported under international agreements has not been of the highest quality is evidence that there is a serious need to reexamine the way in which we do business in this area. It is expected that whatever the precise distribution of management responsibility which results for 1984, joint planning by and closer cooperation between STIA and the research directorates can lead to a higher quality of science project support and thus, in the future, to an enhanced degree of collaboration between U. S. and foreign scientists.

QUESTION: Just how will the proposed management shift enhance NSF programs for women since these programs are now judged according to special criteria and obviously candidates will not compete successfully against most male candidates?

ANSWER: Several points are important here:

1) The principal review criteria which are used in the research directorates are also used in the Visiting Professorships for Women (VPW) program -- quality of the proposed research and research qualifications of the principal investigator. These same criteria are also used in the other "special programs."

2) In the VPW program, approximately 39% of the proposals had average reviewer ratings of "excellent" to "very good" (or 5.0 to 4.0 on a 5 point scale with 5 as the highest rating). For the Foundation as a whole, 26% of the proposals are found in this same category.

3) In the research directorates, the effect on decision of investigators' sex and proposal quality as judged by reviewers has been examined by the Office of Audit and Oversight. The results of their analysis shows that for proposals of equal quality, the effect of investigators sex on success ratio is not significant.

4) Only about 9%-11% of all proposals submitted to the NSF are from women.

It is this last item that the proposed distribution of management responsibility is likely to affect. It will be a part of the responsibility of the research directorate program officers to encourage the submission of more proposals from women and to bring more women into the research efforts of the NSF.

QUESTION: Some of the programs to be shifted were congressionally mandated and are compensatory in nature, such as undergraduate college research support, visiting professorships for women, experimental program to stimulate competitive research (to insure geographic distribution). Obviously, proposals for these programs cannot be judged along side non-compensatory or non-equity programs. What assurance can you give that support for nurturing and funding these programs will be maintained?

ANSWER: There seems to be a misperception of the basis for judging proposals for the so-called "special programs". In each case, the quality of the research proposed and the research qualifications of the principal investigator are overriding. Sheltering, or separating, such programs ensures that a minimum amount is provided for them. Often there are many more meritorious proposals than funds available will allow. When separated like this, there is no incentive for monies to be shifted to these areas to allow funding beyond the minimums. Under the proposed distribution of management responsibility it would be possible that, more not less funding, be provided for these activities. Program offices will be expected to pay attention to the whole range of research issues in their discipline and to fund the very best ideas. The Director has charged his steering group to develop a tracking system so that we will be able to determine how we are doing in these program areas so that mid-year corrections may be made if necessary.

QUESTION: The Director's memo to the Executive Council of Jan. 12, outlining the new management philosophy attributes the shift in part to the fact that programs outside the research directorates have not endured or are not viewed as central to NSF's mission. However, these factors would seem to be the major reasons not to decentralize support. The programs are often problem-oriented (RANN, support for women and minorities) or politically expedient (many bilateral programs). Does NSF really expect programs of this nature which are so tangential to the fundamental NSF missions (basic research and education) to compete successfully for funding in the research directorates?

ANSWER: That the perception exists that the "special programs" are in some manner "tangential" to the fundamental missions of NSF is one outstanding reason for highlighting these efforts and making them an integral part of the responsibilities of all of the Foundation. These activities are not tangential. They are research and education activities which are judged by the same review criteria that proposals submitted to the research directorates are. They are a part of a whole range of scientific issue areas that must become a part of each program officer's cognizance if the overall health of the U.S. science is to be served.

QUESTION: The Director states, that the present management system is suboptimal because it has deemphasized the educational aspects of research, in favor of procurement of new knowledge. This did not occur in the last three fiscal years (support of graduate students via research activities increased from 9,341 to 10,428, etc. in FY 1984). On what basis does does the Director make the statement that the educational aspects of research have been deemphasized?

Just how will this reorganization expand or give "prominent recognition," as the Director requests, to programs for support of graduate students via research awards? Will science education at other levels be given prominence also?

Just how will be proposed management shift enhance NSF programs for the support of precollege science education?

Which science education programs will be shifted to the research directorates?

ANSWER: It is the Director's view that in the past, education and research have often been perceived as two separate entities, with their interdependence minimized. In the FY 1984 budget presentation we have attempted to show that it is not possible to have a healthy enterprise without: (1) a strong, high quality human resource pool from which to draw future scientific workers; (2) a high quality total educational system; and (3) quality advanced research instrumentation. These three factors are interrelated and are necessary to produce a strong, vital research effort. The continuum of the educational base extends from primary and secondary schools, through undergraduate schools and on to post doctoral experiences. As students experience each of these levels, they make career choices which are influenced by the quality of the faculty and the teaching they encounter along the way, and the opportunities they have to be a part of the research process.

The distribution of management responsibility will not in and of itself give prominence to graduate student support. Rather, education concerns will become an increased part of the responsibilities of research directorates. They will be expected to encourage the participation of undergraduate faculty in their research areas in appropriate ways.

While responsibility for precollege science and mathematics education will continue to be centrally managed, research directorates will be asked to play a more prominent role in planning future NSF activities in this area. No programs currently located in the Office for Scientific and Engineering Personnel and Education will be shifted to research directorates.

QUESTION: On p. NSF-20 of the FY 1984 justification, it is stated that NSF planning and evaluation activities will be shifted to the research directorates. How will NSF overcome the readily apparent conflict of interest that will result from the research directorates conducting and supporting evaluation activities of their own programs?

ANSWER: NSF evaluation activities are conducted in several modes:

1) The Office of Audit and Oversight, which reports directly to the Director of the Foundation, conducts (or contracts for) evaluations of selected program activities, often at the specific request of the Director or the National Science Board.

2) Divisional or directorate advisory committees evaluate individual program areas on a three-year cycle and report their findings directly to the Director.

3) Programs may on occasion support evaluations of special topics or whole programs using their own program funds.

In the FY 1984 budget justification, funds for evaluation activities are aggregated and displayed here for convenience of showing magnitude of effort. No change in organizational responsibilities are planned for these activities.

APPENDIX

ADDITIONAL INFORMATION FOR THE RECORD

SUMMARY OF HEARINGS ON THE NATIONAL SCIENCE FOUNDATION FISCAL YEAR 1984 AUTHORIZATION BILL, HELD BY THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY, HOUSE COMMITTEE ON SCIENCE AND TECHOLOGY

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June 6, 1983

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SUMMARY OF MAJOR RECOMMENDATIONS MADE BY WITNESSES DURING THE HEARINGS

The following is a summary of some of the major recommendations witnesses made during the hearings, as noted in the text which follows.

1. The National Science Foundation's (NSF) programs for pre-college science and engineering education are inadequate; the Foundation should take a leadership role and provide more, as well as more structured, support for this area.
2. NSF's new undergraduate college science support program does not meet the needs of undergraduate schools. It should be revised to permit more research on the undergraduate campus and support for faculty at teaching institutions.
3. Consideration should be given to Federal support for salary augmentation for high school and college science teachers.
4. More financial support is needed for the U.S. oceans research program, specifically for basic research and for the academic ocean sciences fleet.
5. The United States needs to develop an oceans satellite survey system.
6. Federal support levels, especially in NSF, are inadequate to meet the Nation's needs for improving instrumentation in universities. Funding should be increased; university researchers should be allowed to use equipment at national laboratories; mission-agencies should set-aside funding for instrumentation needs.
7. To enhance contributions by industry for equipment and instrumentation under the Economic Recovery Tax Act of 1981 (ERTA), the Internal Revenue Service should issue implementing regulations for ERTA.
8. In order to increase university donations of equipment, ERTA should be revised to allow the fair market value of the donated equipment to be allowed as the tax credit base.
9. Legislation should be enacted to amend section 102 of the Internal Revenue Service Code to make any kind of funding tax-exempt for university equipment purchases.
10. NSF should examine the full consequences for dilution and mismanagement of "special programs," before undertaking the proposed reorganization of the Directorate for Scientific, Technological, and International Affairs.
11. NSF's views that social and behavioral sciences research needs less instrumentation than physical and natural sciences are incorrect and NSF should increase funding for instrumentation-intensive aspects of behavioral and social sciences research. NSF should mount a study to identify instrumentation needs of the various disciplines.
12. NSF's funding for behavioral and social sciences research and for information science and technology is inadequate and should be raised.

SUMMARY OF FISCAL YEAR 1984 NATIONAL SCIENCE FOUNDATION AUTHORIZATION HEARINGS

The Subcommittee on Science, Research, and Technology of the House Committee on Science and Technology held four days of authorization hearings on the National Science Foundation (NSF) in February and March 1983; the full committee held a one-day posture hearing on the Foundation in February. The major issues discussed were: science and engineering education; astronomical and ocean sciences; instrumentation, behavioral and social sciences; and information sciences. This is a summary of the transcripts and testimony submitted by the witnesses.

I. INTRODUCTION

A. Relevance of NSF's Mission to Presidential Goals

In his statement at the posture hearing on NSF, held on February 23, 1983 the NSF Director Dr. Edward A. Knapp quoted a recent speech by President Reagan to the "Massachusetts High Tech Council Forum," in which he underscored the importance of research to economic revitalization of the Nation and of the need for governmental involvement in these processes:

> We will propose unprecedented increases in fundamental research, because it offers essential support for our industries and our defense needs. And we will channel this research into the most promising areas--those most likely to extend the benefits of American science expertise to industry. As you know, research is the wellspring of ideas that lead to new technologies such as the transistor and the laser. And it is, also, the key source for the highly trained scientists and engineers that . . . we will need to lead us into the next century.

Dr. Knapp defined NSF's mission in the context of these goals: "The type of fundamental research NSF supports makes a central and creative contribution to the economic health and vitality of this Nation." NSF's mission, he explained, differs from missions of other Federal agencies since the Foundation focuses specifically on basic research, especially in universities:

> The FY 1984 investment in research and development by the Federal government is estimated at about $46 billion. The major R and D funding agencies are the Departments of Defense, Energy, Health

> and Human Services (including NIH), and NASA. With our $1.3 billion proposed total budget for all the Foundation's responsibilities, the NSF is not a leading factor in the overall investment for research and development by the Federal government. But, if one looks at the Federal investment for basic research, one can see that the Foundation plays a significant role in ensuring the health and vitality of the Nation's research enterprise. Historically, the Nation's colleges and universities have been the institutions in which most long-term, fundamental research work is carried out. In the support of basic research at universities, the Foundation accounts for about three-fourths of all Federal funding and trails only the National Institutes of Health--which concentrates its funding on health-related research.

NSF's budget request for fiscal year 1984 totaled $1292.3 million, an increase of 17.8 percent over the current plan for fiscal year 1983. "The requested rate of growth in the Foundation's budget over previous fiscal years, and the emphases contained in this budget," according to Dr. Knapp, reflect three things:

> First, the importance of basic research in laying the groundwork for long-term economic growth, and providing a foundation for the technologies on which our national security and other goals depend. Second, the need to revitalize our research base in the Nation's colleges and universities and to ensure their continuing ability to produce "world class" scientists and engineers in the years ahead. And third, the importance of quality education in science and mathematics in our secondary schools for continuing U.S. technological and economic leadership in the world.

Major budget thrusts were requested for research in mathematics, materials, engineering, earth sciences, and instrumentation. In addition, as a response to congressional criticism, the Foundation reinstated some programs it originally wanted to eliminate , such as engineering research to aid the handicapped.

B. Concern About Whether NSF Is Supporting Applied Research

Congressman Norman Y. Mineta said that during last year's hearing, Dr. George Keyworth, presidential science advisor, testified that basic research was very healthy. The Congressman wondered whether NSF's increased support for basic research would be at the expense of applied research, whether support for applied research has declined since the Applied Sciences and Research Applications Directorate was terminated, and whether NSF could tell how much support goes annually to applied research. According to Dr. Lewis Branscomb, National Science Board chairman, applied research has not declined in NSF and the agency has a tracking system to determine the amount of funds awarded for applied sciences research. But, he said, the National Science Board has decided that a distinction between basic and applied research is not useful. And, he underscored, no Federal Government agency should have an important role to play in supporting applied research:

> . . . [I]f by applied research, you mean problem-solving research aimed at a practical goal which has to survive an economic test, I don't think either the government or the universities are very good at that and that should be left to the private sector.

Several congressman disagreed. Congressman Doug Walgren said that better distinctions should be made between basic and applied research for purposes of congressional oversight. Mr. Mineta said that most companies will not support high-risk research and development, unless a high profit were promised.

C. Appropriate Role of NSF in Planning for Long-range Research and Development

Both Congressmen Mineta and George Brown wondered whether NSF could establish five-, ten-, or fifteen-year goals for basic and applied research. Mr. Mineta said goal-setting was essential to help plan manpower supply; Mr. Brown reasoned that the Nation does not have long-range goals and NSF may have the institutional structure to fulfill such a role. In response, Dr. Knapp said that each scientific discipline has its own ten-year plan. Also, since scientists can move easily from one field to another, there is no overriding need for long-range manpower projections for basic and applied sciences fields. According to Dr. Branscomb, the Foundation can play a leadership role in these areas by establishing a dialogue, using the extensive network of scientists NSF taps to perform various advisory and review functions.

II. SCIENCE AND ENGINEERING EDUCATION

A. Introduction

The fiscal year 1984 request for science and engineering education (SEE) totaled $39 million, $9 million more than the fiscal year 1983 plan, which Congress had increased from a requested level of $15 million (for only graduate fellowships). The fiscal year 1984 budget would allocate $19 million to a program of graduate research fellowships and $20 million to a program of pre-college teacher improvement in science and mathematics. This budget request is still $31 million below the fiscal year 1981 level, and does not include the curriculum development, communication, and research elements of previous years' programs. Subcommittee Chairman Doug Walgren noted that although the requested increase seemed substantial

> . . . past actions have so eroded the base . . . that the increase is not really significant . . . . I would also note that in a budget increase of $195 million dollars [for all of NSF], the $5 million for pre-college education is insignificant by comparison [and] hardly up to the level of a major initiative as claimed by the President in his State of the Union address or as restated in the Foundation's testimony . . . .

Several members of the subcommittee said that there were serious shortcomings in the quality of U.S. science education at elementary, high school, and college levels, with U.S. students performing far below their peers in Japan, the Soviet Union, and Germany. They stated that this has severely eroded U.S. international technological competitiveness.

Five witnesses testified on the subject of science and engineering education:

William T. Coleman, Jr., Co-chairman of the National Science Board Commission on Pre-college Education in Mathematics, Science and Technology;

Edward A. Knapp, Director of the National Science Foundation;

Lewis M. Branscomb, Chairman of the National Science Board;

Jon W. Fuller, President of the Great Lakes Colleges Association; and

Saul Fenster, President, New Jersey Institute of Technology.

B. National Science Board Commission On Pre-college Education In Mathematics, Science, And Technology

In April 1982, shortly after presentation of the fiscal year 1983 budget, when the National Science Foundation, for the second time, sought to eliminate all support for pre-college science education, the National Science Board established the Commission on Pre-college Education in Mathematics, Science, and Technology. The Commission was intended to define principles and strategies to guide pre-college science education efforts in the United States. The goals of the Commision are to:

- broaden the pool of students prepared and motivated for science, mathematics, and engineering careers;

- widen the range of science and mathematics offerings for students who do not intend to pursue science careers; and

- increase the mathematics and science literacy of all citizens.

William T. Coleman, co-chairman of the Commission, testified on its recent activities. The first phase of activities, to define the problem, was described in the Commission's first report, Today's Problems, Tomorrow's Crises. The report's recommendations deal with improving: the curriculum, the condition and status of the teaching profession, public perceptions and student attitudes, and the use of modern technology.

The Commission established four task groups to catalyze activities of governmental officials at all levels, including college-level educators, pre-college educators, and users of the system, such as the military. Upon questioning, Mr. Coleman described a few exemplary pre-college science education programs, in Atlanta, Georgia and Raleigh, North Carolina. The Commission plans to test the reactions to its tentative recomendations at a public forum in Houston. A final report is due in October 1983.

The hearings discussion indicated that improving pre-college science education was complex; while there was agreement on causes of problems, there was none on solutions, a situation exacerbated by the autonomy of the Nation's 16,000 school districts. There seemed to be two major problems. First, that the country is too complacent and needs to be aroused as it was after the Soviet Sputnik launch in 1957, but now toward the goal of competing internationally to improve the Nation's quality of life and industrial output. The second problem is the need for economic, status, and attitudinal incentives to encourage teachers to stay in the profession. In response to a question from Congressman Joe Skeen, Mr. Coleman said that he expected SEE problems to be resolved within five years. According to Dr. Lewis Branscomb, Chairman of the National Science Board, the Board will devote its October 1983 meeting to discussing the Commission's report.

C. Views On National Science Foundation SEE Programs

Regarding NSF's SEE programs, testimony focused on three issues: the pre-eminence of NSF's role in graduate education; the need for more emphasis on pre-college science education; and the issue of undergraduate science education.

1. NSF Responsiblities for Graduate Education Are Paramount

Both NSF Director Knapp and NSB Chairman Branscomb testified that NSF's major science education role is in career development-oriented graduate education and training in the sciences, not in pre-college education. The largest number of graduate students supported by NSF serve as graduate assistants on research grants awarded to their professors. It is anticipated that in fiscal year 1984 this program will support some 10,000 students, at a cost of $92 million, a 16 percent increase over the previous year. Other graduate level programs are fellowship and postdoctoral awards supported from the science and engineering education support program.

2. NSF's Limited Role in Pre-College Science Education Programs

Typical of the comments heard in the last few years, NSB Chairman Branscomb said that NSF has a minimal, very selective role in pre-college science education because such education is not a Federal responsibility. Similarly, Dr. Knapp distinguished between what he perceived as NSF's major role of supporting, via research grants, graduate students planning to become scientists, and its minor role of supporting pre-college students in science education, which, he said, is a responsibility of the States and the Department of Education. For instance, during the posture hearing, Dr. Knapp said:

> The Foundation's role in science and engineering education is basically quite different from its role in research . . . . The ultimate responsibility for education, especially on the elementary and secondary level, has always belonged to the [S]tates and local communities. About $200 billion a year is spent on education in this country, to which the Federal Government contributes less than a tenth. Federal agencies other than NSF play a significant

> role. This is especially true for the Department of Education, whose fiscal year 1984 budget request is about $13 billion. In this light, the resources available to the foundation are so miniscule that they must be used very carefully and selectively.

As the discussion below indicates, many Committee members disagreed, and said that NSF has a major role in pre-college education.

a. Evolution of NSF's pre-college activities. The NSF Director described the evolution of NSF's pre-college science education activities. In the past, because it was necessary, NSF played a larger role in pre-college education, including "science curriculum development . . . teacher training, and . . . development of scientific manpower." NSF, and the then Office of Education, easily resolved potential for overlap, because "NSF would focus on science and operate mainly through the scientific community and through universities and colleges, the primary group with which it had constant interaction . . . . It was NSF's comparative advantage, given its responsibilities for basic research. The Office of Education, in turn, would work mainly through [S]tate and local education systems and focus on the broad application of education." The Foundation had far less money to spend, but "there was widespread agreement that NSF's activities were, overall, well-targeted, well-managed, and effective in meeting their objectives."

The Foundation's functions in this area started decreasing in the 1970s when "scientific personnel shortages were seen to be less acute." But, the Director said: "By 1979, there were 28 different programs in science and engineering education with total obligations of $80 million. Many were targeted at specific, limited problems without a clear connection to a larger conception of the overall nature and needs of science education. It is clear that the consensus which existed in the 1950s and 1960s on the nature of these needs and on the strategies to be provided had dissolved by the end of the 1970s."

b. Objections to NSF's perception of its limited role in pre-college science education. Congressmen Don Fuqua, Doug Walgren, George Brown and others evidenced concern that the National Science Board and the National Science Foundation had long ago chosen to abandon their congressionally mandated roles in pre-college science education and had reaffirmed this decision in 1981, and again in 1982, when the Foundation sought no funding for pre-college programs. During the posture hearing, Committee Chairman Fuqua described this belief and linked it to introduction of the committee's bill, H.R. 1310, to increase funding for pre-college science and engineering education, in an attempt, he said "to correct a problem that was created by NSF because NSF neglected its responsibilities in the area of science and education." H.R. 1310, would appropriate an additional $130 million to NSF for pre-college, post-secondary and public science and engineering education (for summer institutes and workshops, post-secondary faculty development, educational research, and a science and engineering personnel fund). These funds would complement NSF's $39 million request for SEE, which was limited to programs of pre-college teaching improvement and graduate fellowships.

In response to the charge of neglect, Dr. Branscomb testified that NSF and the Board had not abrogated their responsibilities even though no funding had been requested for pre-college activities. He said that the Board issued statements on its responsibilities in this area in March and August 1981 and initiated the positive step of creating its Commission. He did say, however, that there was a certain amount of "constructive tension between the National Science Board and the new President." But, contrary to what many thought,

> [the new Commission was not set up] for the purpose of defraying pressure on us to be specifically active in a programmatic fashion. As a matter of fact, quite the contrary. We established the [Commission] in order to generate that pressure. But we felt the pressure ought to be generated on the citizens of this country, by themselves, not just on the Congress and the Science Foundation.

Dr. Knapp described NSF's current pre-college science education responsibilities, primarily hortatory in nature, as follows:

> NSF will always have a limited but critically important role, in pre-college education within its basic charter and overall responsibility for the health of science. In fulfilling these responsibilities, it is incumbent upon the Foundation to select and design its activities in such a way as to exert high leverage; demonstrate leadership in the national interest through example setting, and prototype testing; involve research scientists and engineers in educational concerns; be as flexible as possible and receptive to new ideas; and to promote the involvement of [S]tate and local governments, and the private sector, in its undertakings.

He described the two presidential initiatives NSF would fund in 1984: the Presidential Awards for Teaching Execllence in Science and Mathematics, for secondary school teachers; and the Presidential Secondary School Science and Mathematics Teaching Impovement Program, to train teachers.

Many Subcommittee members and witnesses said that NSF's current pre-college science education programs were inadequate to meet national needs, and therefore, favored passage of H.R. 1310. NSB Chairman Branscomb said he personally endorsed Title II of the bill, a matching grant program which would alleviate such problems as faculty retention, equipment and materials acquisititon at all levels, and aid public understanding of science. He said it was "congruent with our enabling statute." Dr. Knapp commented favorably on another part of Title II, which would require NSF to develop technician training.

Congressman Judd Gregg asked Dr. Knapp whether NSF would reestablish a directorate for scientific and engineering education if H.R. 1310 were enacted. Dr. Knapp said that such a decision depends on the size of the resulting program and the way the bill prescribed its functions.

As another illustration of criticism, Congressman Brown wondered why NSF was terminating funding for the widely acclaimed children's TV science program, "3 2 1 Contact." Mr. Knapp said this decision was being reviewed.

Dr. Saul Fenster, President of the New Jersey Institute of Technology, representing the American Association of State Colleges and Universities and 20 educational associations, referred the Subcommittee to a report entitled, "Higher Education's Agenda in Science and Mathematics and Technology Education," prepared by the Association he represented. Citing the report, he recommended that NSF should play a major role in restoring the health of American science education. As an example of a successful NSF support program, he described the Center for Pre-College Programs for disadvantaged students at his institution. NSF support was a crucial catalyst in stimultating industrial investment, at a level two and one-half times the amount of Federal support. It is especially important, he said, for scientists to be involved in developing summer institutes since the Department of Education cannot provide the expertise that NSF can. He urged the Committee to consider suggestions contained in the aforementioned report to strength NSF's pre-college science education. These included programs to:

- provide opportunities for teachers, young scholars and researchers through expanded graduate fellowships, new traineeships, and faculty research awards;

- upgrade and improve instructional programs at all levels;

- upgrade instructional equipment and its utilization; and

- strengthen educational research relating to cognitive science and instructional uses of computers.

3. The Issue of NSF Undergraduate Science Education Programs

According to Dr. Knapp, science and engineering education support programs at undergraduate colleges are important since

> . . . these colleges serve as an important pipeline for entry into the system of graduate education, and finally into the overall scientific and technical enterprise of the country . . . .

He furnished some supporting data: during the period 1967 to 1976 about 9,500 Ph.D recipients in chemistry received their B.A degrees from 198 undergraduate schools. In 1982, 20 percent of NSF graduate research fellowships went to graduates of such schools. This year the Foundation proposed a new program, Undergraduate College Research Support, to be funded at the level of $3 million. It would give faculty of undergraduate schools the opportunity to conduct research at other larger academic institutions, or Government and industrial laboratories, and would provide a modest amount of support for purchase of new equipment for undergraduate institutions.

Dr. Jon Fuller, representing tweleve undergraduate liberal arts colleges, testfied that the Foundation's programs did not go far enough in meeting the needs of undergraduate institutions. He criticized the proposed NSF undergraduate program on the grounds that research should be carried out on the undergraduate university campus in preference to other locations. He also said NSF should take the lead in supporting specialized undergraduate training of science teachers. Reacting negatively to the NSF response for support of undergraduate education, he said: "We have not found the kind of attention from NSF . . . that we think is appropriate to this part of the educational continuum." Attention should be given to such other program initiatives as:

- research by faculty members, which should be supported by a small set-aside in the NSF budget;

- development of opportunities for professional renewal by faculty at predominantly teaching institutions;

- support for instrumentation needs;

- support for computing equipment needs;

- development of a program of periodic review and improvement of science institutions, such as interdisciplinary curriculum projects supported by joint efforts of the National Science Foundation and the National Endowment for the Humanitities.

a. Augmenting teachers' salaries and matching programs. The subcommittee also discussed the issue of raising salaries for mathematics and science teachers. The Director described a new program, Presidential Young Investigator Awards, for research to encourage young scientists and engineers to stay in universities, rather than move to industry where salaries are significantly higher. The program would provide up to 200 awards annually, each to last up to five years, with the average award at $30,000. This would be a matching program with industry supplying half of the funds. One witness said that EXXON has begun a young faculty salary supplement program for college level teachers. Congressman Herbert H. Bateman suggested that perhaps Congress should allocate some funds proposed for science and engineering research to serve as economic incentives for salary increases at various teaching levels. But Mr. Fuller disagreed, and said that the institutions themselves, States, and localities, not the Federal Government, are responsible for salary augmentation and competition. But, he added, "There are, unfortunately, legislative and contractual restrictions particularly from the publicly supported structure which make salary enhancement impossible."

Regarding the potential for matching programs, Dr. Branscomb said they would succeed only if the matching is by "faculty salaries in kind," which would not require States to put up any additional funds for State institutions. However, Dr. Fenster cited the following as potential disadvantages of a matching program: poor geographic location, i.e., distance from an industrial or corporate center, which would disadvatage smaller schools; small size, which might weaken fund raising efforts; and difficulties arising from having to return over and over again to the same firms for funding.

b. Use of computers in education. Mr. Brown asked the NSF Director to discuss the possiblity of recommending to the President establishment of a commission, similar to those in Sweden and Japan, to deal with the uses and implications of computers in all areas of society, including education. Dr. Branscomb said the Board plans to discuss NSF's internal organization and priorities in information sciences, computer engineering, and computer science.

III. ASTRONOMICAL, EARTH AND OCEAN SCIENCES

A. Introduction

The second day of authorization hearings was devoted to the topic of the astronomical, earth, and ocean sciences, supported by the Directorate for for Astronomical, Atmospheric, Earth, and Ocean sciences (AAEO). Witnesses were:

NSF Director Edward A. Knapp and Dr. Edwin E. Salpeter, National Science Board;

Dr. Jacque Cousteau , oceanographer and naturalist;

Panel on Oceanography and Ocean Drilling

Dr. Charles L. Drake, Dartmouth College and Chairman, Ad Hoc Advisory Group on Crustal Studies;

Dr. William Nierenberg, Director, Scripps Institution of Oceanography;

Dr. Derek W. Spencer, Woods Hole Oceanographic Institution; and Director of the University National Oceanogrphic University System.

Panel on Astronomy

Dr. George B. Field, Chairman, NAS Committee on Astronomy; and

Dr. Arthur D. Code, President, American Astronomical Society.

Subcommittee Chairman Walgren opened the hearing by underscoring the importance of research conducted by the directorate:

> . . . The research sponsored by this directorate has, more than any other single program, revolutionized our view of both our planet and the universe in which we live.

He cited, in particular, understanding of: continental drift; quasars; pulsars; red dwarfs and black holes; development of oceanographic research instrumentation; research submersibles; and deep water drilling techniques, with potential relevance to commercial resource recovery.

B. National Science Foundation Description Of The AAEO Program And Requested Funding Levels

NSF Director Knapp explained the requested funding levels for fiscal year 1984. He was seeking a 21.3 percent increase in funding for the directorate. The biggest increase planned, 25.9 percent, was for the astronomical sciences. "The increase," he said, will allow us to upgrade instrumentation at university and national observatories and to support preliminary design studies for the very long baseline array . . . a major, new radio telescope . . . . " Funding for atmospheric sciences would increase by 20.7 percent over the fiscal year 1983. The requested increase for the earth sciences was 23.5 percent over the fiscal year 1983. According to Dr. Knapp, "The increase will allow year-round, continental reflection profiling operations and general upgrading of much of the research instrumentation which has become obsolete since the major Federal equipment investments of the 1960s." Overall, ocean sciences and ocean drilling research would increase by 18.1 percent. This request includes funds for crustal research to be conducted by the ocean drilling program, which, pursuant to a recommendation made by a committee of earth and ocean scientists, now under study by the National Science Foundation, would use a new commerical drill ship rig, rather than the vessel, GLOMAR CHALLENGER. Funding for Arctic research would increase by 19 percent.

Dr. Knapp offered several reasons to explain the substantial increases in funding for this directorate. A primary characteristic of the astronomical, atmospheric, earth and ocean sciences are that they are observational and the phenomena of interest cannot be controlled or manipulated as in laboratory sciences. This means that these sciences are highly dependent upon instrumentation, such as:

> drilling platforms, astronomical observatories, aircraft, ships, and submersibles for observations from the best locations; specific data collecting devices such as radio telescopes and receivers, charged coupled detector arrays, seismic detectors, earth corers, or doppler radars; and storage and computational equipment for handing data, facilitating its interpretation and modelling natural phenomena.

National Science Foundation support is rendered four ways:

- direct support to individual investigators;

- support of national centers and other major research facilities;

- support for large coordinated projects; and

- indirect support of many investigators who are given access to facilities, data, or samples on a competitive basis. The major facilities supported by NSF are:

- five user-oriented national astronomical observatories, plus partial support of a half dozen university observatories that operate a range of radio telescopes;

- a longitudinal chain of back scatter radars to observe winds and other phenomena in the upper atmosphere at locations from Greenland to Peru;

- the National Center for Atmospheric research (NCAR), which both conducts staff research itself, and provides major computational and modelling facilities, aircraft, and radars to university researchers;

- seismic reflection profiling by the Consortium for Continental Reflection Profiling (COCORP) to map the structure of the continental crust to depth of 70 kilometers;

- the ocean drilling ship CHALLENGER . . . ;

- with NOAA and the Office of Naval Research, the manned submersible ALVIN; and

- the . . . operations of 22 of the 25 ships currently constituting the academic oceanographic fleet.

The amount of individual project support varies from field to field, with the largest amount going to researchers in the earth sciences. The Foundation coordinates its programs and funding with those of other agencies via informal contacts, as well as formal mechanisms, such as the Committee on Atmosphere and Oceans of the Federal Coordinating Council on Science, Engineering, and Technology.

In most of these sciences NSF provides the bulk of Federal funding to universities. According to Knapp:

> The Foundation is a major supporter of academic research in all the AAEO sciences though the magnitude of its role varies, depending on the levels of funding for more mission-oriented research provided by other Federal agencies. The NSF is the lead agency for Federal support of ground-based astronomy and, since 1976, has maintained a relatively constant funding role providing about two-thirds of the Federal total. In atmospheric sciences

research, the National Oceanic and Atmospheric Administration (NOAA), the Department of Defense (DOD), and the National Aeronautics and Space Administration (NASA), are major sources of support, with NSF funding accounting for only about half of the work conducted by university investigators. The U.S. Geological Survey, NASA and Department of Energy are important funders of applied, mission-oriented work in the earth sciences with the Foundation accounting for about 75 percent of the Federal funds going to universities for the support of basic research in these disciplines. Similarly, the NSF provides nearly three-fourths of the Federal support of basic ocean research at academic institutions. The significance of the Foundation's role in the ocean sciences in recent years has increased because of general decreases in funding levels for basic and applied oceanographic work in other Federal agencies.

C. Oceanographic Programs

Several witnesses stressed the need to increase funding for basic research in the oceanography area.

1. Need For More Basic Oceanic Research

Dr. Jacques Cousteau testifed that U.S. basic ocean sciences research budgets have been declining since 1968 due to cutbacks in DOD funding for basic research and greater U.S. emphasis on applied, rather than, basic research. Unfortunately, other countries have followed the U.S. lead, but U.S. leadership in science and techmology, he said, has declined most precipitously. He recommended that the following oceanic research areas receive more funding:

- real-time data collected daily from research bouys interrogated by satellites;
- support for an oceanographic measurement seaplane;
- study of the four air/ocean interfaces:

  > air/ocean where climates are conceived; ocean bottom interface, where continents and ocean basins are forged, where minerals are generated and nutrients regenerated; the coastline provinces where the human pressure is highest. . . ; and finally, the fresh water/salt water interface at deltas and mounts of large and small rivers, and of various run-offs; and

- more interdisciplinary research, which he labeled "ecotech"; and
- replacements in links in the food chain in oceans.

"Ecotech" research is holistic in nature, and differs from current reductionist paradigms, which are overused, he said. This new kind of research would "integrate [study of] human-oriented disciplines with natural system subjects." Dr.Cousteau stressed that "We must embrace ecology, economics, and with appropriate technology, develop alternate futures to insure a healthy and productive biosphere." At NSF this would mean more support for population ecology and ecosystem function. Specifically:

> We need to understand the patterns of the landscape including coastal regions, the human and natural systems which survive in these regions, the distribution and exchanges of energy and matter, the controlling role of water, feedback loops within these systems, and we need to be able to evaluate alternate futures in light of such models.

Dr. William Nierenberg agreed with Dr.Cousteau's recommendations and said that "we are losing ground" in these areas. "The problems are coming at a rate and an intensity that seems faster than . . . our social science ability seems capable of coping and developing."

Members of the oceanography and ocean drilling panel outlined other research needs.

2. Importance of Deep Sea Drilling

Dr. Charles L. Drake testified on the importance of basic oceanography and crustal research in the context of geology and geophysics and, in this connection, stressed the importance of deep sea drilling tools, essential to obtain the data needed to produce better models of the resources of the ocean bottom and beneath. It is essential, he said, to understand the past processes of formation of layers of the ocean bottom to clarify basic uncertainties. He illustrated this point with several examples of the breakthroughs from ocean drilling:

> Scientific ocean drilling provided the confirmation for the model of the ocean crust by seafloor spreading from ocean ridges, a model suggested from geophysical measurements. Drilling demonstrated the presence of salt domes and hydrocarbons in the deepest parts of the Gulf of Mexico.

Two recent developments in drilling technology, the "Hydraulic Piston Corer" and the "Extending Core Barrel," allow researchers to recover undisturbed samples, giving the history of ocean basins and waters and of climates above ocean surfaces. Dr. Drake said that "An important opportunity would be lost if ocean scientific drilling were to be terminated."

3. Need for More Research on the Links Between Climate Change and Oceanic Patterns; Need for an Ocean Satellite System; Impacts on Defense and International Politics

Dr. Nierenberg testified on the need for researchers to understand the links between oceanic phenomena and short-range climate change, as well as the impact of the oceans on longer range climate prediction and on political decision-making with international economic implications. He stressed the importance of oceanic patterns on fisheries industries and international politics, citing the failure of the California sardine fishery industry and of the Peruvian anchovetta industry. Specifically, he testified:

> The initial and still important indicators [of climate] are the anomalous sea surface temperatures one finds in the North Pacific. To see what is ahead, it is good to review the recent past.
>
> Namias predicted the fateful drought in the U.S.S.R. [sic.] that prompted the abnormal Russian purchase of grain from the United States that precipitated stringent controls on future deals. This was followed by an abnormally severe "El Nino" that we now know was not unrelated. That event triggered a total collapse of the Peruvian anchovetta fishery that was the principal fish meal supply for mainland China and Japan. Japan, in turn, tried to replace this protein with American soybeans, but President Nixon felt compelled to embargo the crop because of dangerously depleted corn and wheat reserves in this country. This international contratemps need not have occurred if official Washington had paid closer attention to Namias' predictions.

Part of the problem in conducting oceans-related research, according to Dr. Nierenberg, is that meterologists "have, for many years, been very slow in recognizing . . . that the origin of their subject is in the oceans." Furthermore, it is more expensive to make measurements over the ocean than over land. But the consequences of not doing so are also costly. He stressed that in order to obtain better predictive results, the United States should develop an ocean satellite system, a continuous system linked to the modelling capabilities of high speed computers. SEASAT, he said, was operational for only 99 days.

He also listed other research areas requiring NSF support:

- evolutionary change vs. the effects of carbon dioxide in the atmosphere, including ocean dynamics and chemistry of carbon dioxide absorption in the oceans and the regional effects of carbon dioxide-induced climate change;

- changes in the frequency of natural disasters;

- the issue of sea-level rise;

- understanding of ocean phenomena in relation to defense and the vulnerability of submarine defense and world stability;

- ocean mesoscale eddies and implications for acoustic anti-submarine warfare; and

- ocean sediments; and polar ice and circumpolar currents.

Dr. Cousteau told the Subcomittee that international cooperation under the auspices of intergovernmental organizations was inefficient and that such cooperation should be limited to collaboration among three to five nations, sanctioned by multilateral agreements. Overall, he implied that nationalistic politics prevent successful multinational collaboration and he cited the fact that political factors allowed the U.S. SEASAT satellite to be focused on only U.S. coastal waters, when it had a capability to scan the entire ocean and provide the data cheaply to other users.

4. More Support Needed for Academic Ocean Sciences Research

Dr. Derek W. Spencer focused on the stresses caused by funding cutbacks for academic ocean sciences research, especially for the academic oceanographic fleet. He said the fleet consists of both general purpose vessels and special purpose vessels, such as the drilling ship the GLOMAR CHALLENGER, the stable platform FLIP, and the submersible DSRV ALVIN. The fleet decreased from 35 vessels in 1971, to 25 in 1983; funding cutbacks have also made it difficult to keep ships in top operational form. Dr. Spencer described the financial problem as follows: NSF supports about 50 percent, and the Office of Naval Research (ONR), about 25 percent, of academic ocean sciences research. These two agencies also provide about 80 percent of support for academic fleet operations. During the period 1969 to 1973 academic oceans science prospered, but since 1973 academic oceans science funding has decreased each year by about 8 percent in terms of constant 1972 dollars.

There are other problems: higher than average inflationary costs; competition from industry for high quality staff; growth in government laboratories conducting basic and applied ocean sciences research; and increased difficulties and costs in obtaining clearances to work in foreign waters.

The following, according to Dr. Spencer, constitute the cumulative effects of the aforementioned problems:

- severe competition in funding and retrenchment in both manpower and facilities;
- pressures on academic oceanographic institutions that fund researchers;
- only proposals for short-term research tend to be submitted because of a low probability of success; and
- research expeditions in regions remote from the U.S. shores are becoming very difficult to plan and execute.

Dr. Spencer said the 10 percent increase in the NSF ocean sciences budget was inadequate, since it was only one-half of the percentage increases in other areas. He urged that the budget be increased more and that the Congress encourage the Navy and other Government agencies to use the resources of academic oceanographic institutions.

5. Continuation of the Ocean Drilling Program by Lease of a Commercial Drilling Rig

Several witnesses addressed the issue of how NSF should, most expeditiously, continue the ocean drilling program. Dr. Drake described the work of the NSF Ad Hoc Committee To Review Plans for Ocean Scientific Drilling in the Context of Crustal Studies and its likely forthcoming recommendation to consider using a leased commercial oil drilling rig instead of the NSF ships, the CHALLENGER or the EXPLORER. NSF Director Knappp said that at least six such rigs were available on favorable terms. According to Dr. Drake, the rigs were available because the market for commercial offshore drilling rigs had collapsed. Conversion of the EXPLORER for ocean drilling was rejected since costs would be prohibitive--on the order of $90 million--and industrial participation had been withdrawn. Conversion of the CHALLENGER was considered, but it also would need extensive overhaul; it would not have the capacity; and it was required for other uses. According to Dr. Drake, front-end costs to equip a commercial vessel would be about 10 percent of costs to convert the EXPLORER. However, he said other costs, in the form of research foregone, might be incurred by giving up the EXPLORER:

> What we would lose would be the ability to drill controlled holes in deep sediments and water over 6,000 feet deep. But I go again to the chairman of the COSAD report, the Conference on Ocean Scientific Drilling, who took note of the fact that almost everything that they propose as a scientific challenge the drill could be applied to could be done on the vessel we are talking about.

Congressman Walgren asked Dr. Knapp why funding, totaling approximately $21.5 million, had been spent on the ocean margin drilling program after the program was supposed to have been completed using CHALLENGER. The response was that about $15 million went to scientific planning--to determine the future of the program and to study alternative designs for continuation of the drilling program (that is, refurbishment of an existing vessel or lease of a new rig). About $6 million of the $21.5 million was provided by industry or foreign nations.

The Foundation requested $9.8 million in the fiscal year 1984 budget to continue the program through whatever option the agency selects. Dr. Drake said that ocean drilling using a new option would be a potential area for fruitful international cooperation and recommended that one-half of the funds for the program should come from foreign contributors. But, Dr. Knapp estimated a much smaller role for foreign partners: "If we go forward with the leased ship, we would go to our partners and solict 1984 contributions to defray planning costs and it would be much less than $1 million, perhaps $200,000 to $500,000 or so per partner."

D. General Satisfaction With Astronomical Research Support Programs

Arthur D. Code, President of the American Astronomical Society, testified on astronomical research. He said that "astronomy has witnessed an unprecedented growth of discovery . . ., the roots of which lie in our ability to explore the entire electromagnetic spectrum, from radio through infrared, optical, ultraviolet, and x-ray." He described some important recent findings made using this technology. But, now we need a "national program of astronomical research, . . . an integrated program that spans the electromagnetic spectrum . . ." because different instruments, receiving different wavelength frequencies, reveal major variations. Specifically, he said:

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The radio telescope reveals a very different universe than does an optical telescope while observations from space of the x-rays shows us the high energy phenomena. Only by putting together all of this information do we get a comprehensive picture. For example, a cluster of galaxies when observed in the x-ray region shows a cloud of very hot diffuse gas in which the optical galaxies are immersed. In the radio region, radio bright galaxies often show large lobes of non-thermal gas much larger than the star filled main body. These radio lobes are due to the ejection at very high velocities of matter from the galactic nuclei. In a cluster these radio lobes are sometimes observed to trail behind due to the motion of the galaxy through the intergalactic medium. Only by obervations in all three spectral regions can these processes be understood.

Dr. George Field was chairman of the National Academy of Sciences' Astronomy Survey Committee, which made recomendations in its report Astronomy and Astrophysics for the 1980s, for two major initiatives--the very large baseline array radio telescope, and the new technology telescope--to carry out research across the entire electromagnetic spectrum. Overall the report recommended programs which would cost $1.9 billion in the decade of the 1980s. This would require a sustained 30 percent increase in funding for the NSF Astronomy Division programs. Together the two telescopes would cost $150 million. Dr. Field said he was pleased that NSF would be doing work in fiscal year 1984 on both of these telescopes.

Dr. Field noted that the Astronomy Survey Committee had made other recommendations for instrumentation detectors, theory, and laboratory astrophysics. He was very pleased that there were no areas in which the NSF budget was unresponsive to the report's recommendations. He cautioned, however, that

> . . . There will need to be substantial increases, starting in fiscal year 1985, in order to proceed with the orderly construction of VLBA and NTT.

The National Aeronautics and Space Administration's budget for astronomy, according to Dr. Field, "does not respond as firmly . . ., even though it is our belief that a comparable effort is required by NASA as given by NSF."

IV. RESEARCH INSTRUMENTATION

The third day of authorization hearings focused on NSF's instrumentation programs for fiscal year 1984 and the issue of university/industry relationships in the area of instrumentation. Witnesses were:

Dr. Edward A. Knapp, NSF Director;

Panel on Instrumentation Revitalization, The University View:

Dr. Donald Langenberg, former NSF Deputy-Director and Chancellor, University of Illinois at Chicago;

Dr. Alvin L. Kwiram, Chairman, Council for Chemical Research;

Dr. George G. Olson, Vice president for research, Colorado State University;

Panel on Industry/university Programs in Instrumentation

Dr. Gerald Mantell, Air Products and Chemicals, Co.;

Dr. Frederick Darnell, E.I. Dupont Co.

A. Introduction: Dimensions of the Inadequacy Of Research Instrumentation

In his opening statement Congressman Walgren noted that last year the Committee heard testimony that it would cost $1-4 billion to remedy the shortfall in university instrumentation. But a recent study by the National Society of Professional Engineers reported that engineering instructional laboratories alone would need $1.2 billion just to restore instrumentation quality to a condition comparable to its condition in 1971. An additional $1 billion would be needed to purchase the equipment needed to cope with increased student enrollment. Thus the estimated cost for engineering instrumentation alone is over $2 billion.

During the subsequent testimony, witnesses gave additional evidence of the cost of upgrading university instrumentation. NSF Director Knapp cited a 1981 study by the American Association of Universities, which reported that $4.4 billion would be required over a three to five year period to upgrade instrumentation at 100 leading academic research institutions. NSF, he said, has begun to develop indicators of this problem. The agency finished a pilot study of 38 institutions in 4 subfields--organic chemistry, cell biology, solid-state physics, and electrical engineering--which indicated that only one-half of the research equipment in these fields is less than five years old and that 65 percent of all equipment was acquired with Federal or partly Federal funds. As another indicator, Dr. Knapp cited the great demand for Federal aid to improve instrumentation. Specifically, in 1983 the Department of Defense announced a $30 million instrumentation support program. But DOD has received proposal requests totaling $600 million. Dr. Donald Langenberg, former NSF Deputy-director and now Chancellor at the University of Illinois in Chicago, said that the propsals DOD received were not a frivolous wish-list because the Department encouraged cost-sharing by the proposing institution, and it was very costly to write the proposals.

Nearly all witnesses described consequences of inadequate instrumentation in the Nation's university laboratories. Typical are Dr. Knapp's comments: "investigators in virtually every field of science and engineering are increasingly dependent upon research instrumentation and computers if they are to conduct leading-edge research in their disciplines." Up-to-date instrumentation is important for both the quality of science that can be pursued and the efficiency of investigators and their ability to train graduate students. Dr. Knapp illustrated the importance of up-to-date instrumentation by citing the development and use of a charged coupled detector array, which was crucial for refining optical and radio telescopes, and the nuclear magnetic resonance spectrometer, which allows a researcher to study living organisms non-invasively.

B. Federal Support Programs for Instrumentation, Specifically the NSF Program

Federal support programs for instrumentation are small in comparison to estimated needs. According to Congressman Walgren, Presidential science advisor George Keyworth testified to the full Committee that about $400 million of the 1984 Federal budget for basic research would go to instrumentation. NSF will supply about 45 percent of these funds, including a new $180 million initiative.

Dr. Knapp said that the NSF fiscal year 1984 budget request would increase funding for instrumentation by 61 percent over 1983; the increase is an Administration initiative and is an "add-on" to the NSF budget. In response to a question from Congressman Judd Gregg, Dr. Knapp said that the NSF program will not solve the instrumentation problem, but "I think taken as a whole, with all of the agencies funding instrumentation at an enhanced rate for the next few years . . . we will be able to make a fair improvement in the problem." Dr. Knapp summarized the highlights of NSF's proposed fiscal year 1984 intiatives as follows:

- o A new equipment program in engineeering which will require matching funds from industry and the grantee university;
- o An instrumentation program in computer research to provide support for the purchase of minicomputers by individual investigators;
- o Partial support for the acquisition of a new sub-millimeter and an optical telescope costing in the $1 - $2 million range, as well as support for improved receivers and processing equipment;
- o Expansion of support of research and equipment at the Cornell Electron Storage Ring, the Illinois Electron Accelerator, and the Indiana University Cyclotron; and
- o Investment in geochemical instrumentation such as mass spectrometers, electron beam instruments, and geophysical detectors to upgrade and replace research equipment in the earth sciences supported originally by NASA and the DOD over a decade ago.

NSF supports instrumentation four ways, according to Dr. Knapp: (1) single investigator; (2) multiuser/multigroup projects; (3) 14 regional instrumentation facilities, each focusing on one scientific area, such as materials; and (4) a limited number of such large-scale facilities as Kitt Peak National Obvservatory and the National Center for Atmospheric Research. On the average, over 10 percent of funds NSF awards for research go for research equipment, with the exact percentage varying from directorate to directorate. The agency, cannot, however, easily track purchases of instrumentation because after funds are awarded to a university professor, "title to the equipment does transfer to the university that gets the grant." Some witnesses suggested that NSF set percentage quotas for NSF funding in each directorate. Dr. Langenberg responded that NSF needs to be flexible. Some directorates require more instrumentation funding than others. There was little or no discussion in the hearing about the issue of how academics themselves may bring on the instrumentation problem by choosing not to purchase equipment with their research funds.

Dr. Knapp noted that the National Science Board adopted a statement in January 1983, which has the effect of telling NSF grantees that it is contrary to NSF policy for them to use NSF-supported research instrumentation or facilities to provide services for a fee.

As for other NSF programs, the agency has experimented with encouraging private instrument manufacturers to make contributions of equipment, on a matching basis, to universities. This effort was sanctioned by a National Science Board statement of October 1982. Congressman Joe Skeen questioned whether the Foundation had encountered problems in finding corporations willing to make matching grants of any kind. Apparently there have not been problems so far, but the potential does exist for pitting one school against another in the quest for industrial support.

C. Activities of the Interagency Working Group on University Research Instrumentation

Drs. Knapp and Langenberg described the activities of the NSF-organized Interagency Working Group on University Research Instrumentation, chaired by the NSF Director. It is composed of representatives from agencies which together provide over 95 percent of Federal support for university research: the Department of Defense; the Department of Health and Human Services; the Department of Energy, the Department of Agriculture; and the National Aeronautics and Space Administration. The group has developed indicators of agency funding for instrumentation, which show an increase of $136 million over the last two years, according to Dr. Langenberg. Other activities have consisted of: reviewing the process for implementing the DOD instrumentation program begun in the fiscal year 1983; discussing possible accelerated cost recovery proposals for university-funded equipment purchase; and discussing concerns by commercial laboratories about competition from universities using NSF-funded instrumentation. In addition, the group adopted a multifacted action program, summarized on chart 1:

CHART 1. Interagency Working Group on
University Research Instrumentation
National Program

	NSF	DOD	NIH	DOE	NASA	USDA
DATA ACOUISITION	X	X	X			
FUNDING INITIATIVES Program Level Increase, FY 82-84, = $136 M	X +90	X +30	X +10	X +6		
STIMULATE DONATIONS/DISCOUNTS	X					
FOCUS SMALL BUSINESS SET ASIDE	X		X	X		
STIMULATE UNIVERSITY MANAGEMENT	X	X		X	X	X
STIMULATE GOVERNMENT LABS		?	?	X	?	

Dr. Langenberg said that universities themselves have to take steps "in the area of managing acquisition, maintenance, and use of research equipment." The Interagency Group is working on a project to help universities use the resources they have "more efficently, wisely and creatively":

> Most of the agencies represented in the Interagency Group have committed themselves to collaborative support of a major project to increase awareness among research universities of opportunities for better planning and management of research instrumentation resources, at all levels from the bench scientist to boards of trustees. The project will be carried out under the leadership of three university organizations, the Association of American Universities, the National Association of State Universities and Land Grant Colleges, and the Council on Governmental Relations. It will include the commissioning of six analyses to:
>
> - o assess the role of debt financing for research equipment in sound university financial practice;
> - o identify and evaluate opportunities to improve the procurement, management, utilization, operation, and maintenance of research equipment;
> - o assess present tax incentives for the donation of research equipment and suggest ways to increase support from the private sector;
> - o indentify opportunities to eliminate or reduce state and university budget and other policy barriers;
> - o identify opportunities for changes in federal regulations;
> - o evaluate present modes of direct federal investment and suggest future improvements.
>
> Also included are plans plans to propagate information and understanding through twenty seminars scheduled to coincide with professional and association meetings, three regional meetings and a national symposium.

As another project, the Interagency Group is considering giving universities access to research instrumentation at national laboratories:

> The laboratories supported by many agencies of the Federal Government are a major national scientific resource, absorb a large portion of the Federal R and D budget, and contain a great deal of highly sophisticated research instrumentation. One is led to ask whether this instrumentation might more effectively be made available to university researchers, where feasible, than it now is. In some fields, such as high energy physics and astronomy, provision of facilities and instrumentation already is the central purpose of federally-funded laboratories. But in other fields and in other laboratories, it may be that laboratory facilities and instrumentation might be used by university researchers, without compromising (and, indeed, perhaps enhancing) the performance of the laboratory.

D. University Views on the Issue of Research Instrumentation

Drs. Langenberg, Alvin L. Kwiram, and George G. Olson testified on the university view on instrumentation.

1. Views on the Inadequacy of Instrumentation

Dr. Alvin L. Kwiram focused specifically on the state of instrumentation in the Nation's academic chemistry laboratories. He represented the Council for Chemical Research (CCR), a non-profit consortium of 40 companies, having total sales for 1981 amounting to about $400 billion, "roughly 15 to 20 percent of the GNP," and 137 universities. The purpose of the Council is to enhance the environment for basic research and joint cooperation in chemistry research between industries and universities.

He said that obsolesence in academic chemical instrumention will lead to continued eroson of U.S. research competitiveness and international economic vitality. The obsolence of university instrumentation affects industry since fewer students are trained with the latest equipment and, consequently, there is a decrease in the innovative capacity. He gave some graphic details on the magnitude of the costly shortfall in chemistry instrumentation. In 1970 it took $10,000 in new instrumentation costs to "start up" a new faculty member; that same member needed access to $100,000 of pooled departmental equipment.

Today new faculty "start-up" instrumentation costs are $150,000, with access to $1 million worth of shared equipment. The increase he said is not all inflationary, but, instead, reflects changes in the way research is done.

2. Views on University Responsibilities for Funding Instrumentation

Several of the witnesses, among them Dr. Kwiram, Olson, Gerald Mantell, and Frederick Darnell, said that the most appropriate type of Federal contribution to universities would be an increase in direct support for instrumentation. However, Dr. Olson, Colorado State University, was also a proponent of the use of debt financing for university equipment needs. This approach does not bring any new money into the university, since loans need to be repaid, but Olson asked rhetorically, "Isn't it time we [universities] helped ourselves?" Debt financing has worked at his institution, leading thus far to purchases totaling $40 million. In particular, it enabled the university to become something of a computer center since, using debt financing, it purchased a state-of-the-art CRAY I computer system, in the late 1970s, which it leases to the National Center for Atmospheric Research and several universities in the Nation via a national computer network.

Olson outlined the benefits of debt financing of scientific equipment. It:

(1) provides equipment now when it is needed;

(2) encourages better management by university administrators;

(3) results in improved equipment utilization (since it usually requires shared use by several researchers); and

(4) develops diversified funding support, including user charges, for equipment.

Several entirely tax-exempt mechanisms are used to finance the debt financing technique, including: revenue bonds; industrial development bonds; municipal lease-purchase contracts; and tax-exempt revolving lines of credit at local banks (used for small pieces of equipment).

The borrowed money is repaid primarily through user fees for both principal and interest. The university uses an affiliated agency, the Colorado State University Research Foundation to manage debt financing because "until the recent amendment to OMB Circular A-21, interest on equipment financing was not allowable [as an overhead cost] unless the instrument was leased from an arm's length agency."

Dr. Olson also described the difficulties of debt financing:

> Debt financing is not easy. It requires the manipulations of many different kinds of financial instruments, the cooperation of investment bankers to sell unrated "story bonds" or "story paper"; and, finally, the careful and expensive opinion of tax counsel. The requirements of OMB Circular A-21, complexities of the IRS code, and the innumberable IRS regulations discourage many university administrators from going forward with an equipment financing program.

Dr. Langenberg endorsed the idea of debt financing, but said university comptrollers would not feel comfortable using such a mechanism to buy equipment. Dr. Olson agreed but said that this should take a businessman's approach and be willing to assume a certain amount of risk. Dr. Kwiram's reservations were on the grounds that a major user of the purchased equipment could pull out and then the university would be hard pressed to pay the debt incurred.

Although the university now uses tax-exempt financing, Dr. Olson said debt financing, using any kind of funding mechanism, would be easier if legislation were enacted to amend Section 103 of the IRS code to make any kind of funding tax-exempt for university equipment purchases. He proposed legislative language to accomplish this goal.

Mr. Gregg questioned whether additional costs over and above costs of direct grants for instrumentation would be incurred by taxpayers if debt financing were more widespread. Mr. Olson said he had no idea.

Congressman BuddyMacKay was concerned about accountability and whether equipment purchased with tax-exempt dollars for higher education could be used for any purpose, such as buying a car. Others wondered if accountability might not be secured better if funding were appropriated directly from NSF or DOD for equipment, rather than indirectly via tax exemptions. Dr. Olson said that football stadiums are bought with tax-exempt bonds and "I just want to be treated as well as a football stadium that's all."

E. Industrial Funding

1. Views on Corporate Contributions to Universities for Instrumentation

Several views were heard on the topic of corporate contributions to universities. Discussing the chemical area, Dr. Kwiram said that is very difficult to convince chemical companies to donate to universities. Today chemical firms donate about $20 million annually to universities, 10 percent of the Federal total for chemistry. They might begin to ameliorate instrumentation problem if they increased their contributions by about $5 million annually, with about 25 percent of that going for the support of instrumentation.

2. Several Kinds of Corporate Support to Universities

Dr. Gerald Mantell, associate director, Corporate Research Services Department, Air Products and Chemicals, Inc., described his firm's innovative instrumentation arrangements with Lehigh University. First, the two jointly established a modern instrument laboratory--a mass spectrometry laboratory--in which they shared the costs for equipment and use. The second example concerned a program in which graduate students are allowed to use the firm's instruments and consult the firm's experts on a joint research program in emulsion polymers. Dr. Mantell said that the firm benefits from this kind of arrangement since the students' questions stimulate lines of corporate research. A third kind of arrangement is leverage from a firm-supplied grant. Specifically, the university leveraged a contribution of $50,000 from the firm "toward partial payment of an instrument to obtain immediate delivery of the instrument and its full use." Like Dr. Olson in the matter of debt financing, Dr. Mantell said that arrangements of this sort involve complex negotiations and significant amounts of personnel time to complete.

Dr. Frederick Darnell, of the DuPont Corporation, described his firm's funding programs for instrumentation. He said DuPont was the first industrial corporation to institute a formal corporate aid program to support higher education in science and engineering. In 1983 DuPont's support to higher education totaled $10.6 million. The firm's higher education grants are unrestricted, but at least 50 percent go to science and engineering, since funds are awarded to selected departments. These funds are not necessarily targeted for equipment, so that university departments can decide themselves how to use the money most effectively.

The company also awarded grants and contracts totaling $4 million in 1983. It often places some ties on such awards, for instance, asking for patent rights or other outputs.

Dr. Darnell endorsed Dr. Olson's idea of universities doing things in a more businesslike manner, but said that unencumbered Federal bloc grants to universities were the most effective forms of aid.

a. Matching university/corporate programs. Matching university/corporate programs, with brokering by NSF, are rare in the chemical industry, Dr. Kwiram said, because chemical firms do not make equipment, as the computer industry does. Usually equipment donated by chemical firms is obsolete; that is, five years or older. Dr. Kwiram outlined the pros and cons of several alternatives for support that the CCR has been working on. These alternatives include:

- more debt-financing by universities;
- refinement of the Economic Recovery Tax Act of 1981 to encourage more firms to donate more equipment or equipment purchase funds to universities;
- development of a cooperative venture among the Federal Government, the States, and and industry to provide matching funds, with the added incentive of the Federal share increasing at a faster rate than the corporate rate, but dependent upon the corporate rate of giving; and
- establishment of a set-aside fund as a percentage of the Federal funds designated for targeted and/or mission oriented R and D [T, R, and D] for instrumentation.

Dr. Kwiram endorsed this last alternative:

> On behalf of CCR, I would like to urge that such an approach be given serious consideration. A set-aside of one-half of one percent of the TR and D budget plus an equivalent amount (somewhat over $100 million) allocated directly to NSF would represent an appropriate response to this problem.

However, right now he said, direct funding by Government seemed to be the most efficacious and expedient route to support the purchase of new instrumentation. He urged the committee to increase NSF's funding for chemistry instrumentation from $6 million to $60 million.

b. Better tax incentives would increase corporate support. There was some discussion of the implications of the Economic Recovery Tax Act of 1981 (P.L. 97-34), which, in part, was intended to provide incentives to manufacturers of scientific instruments to contribute research apparatus to colleges and universities. According to Dr. Knapp, the impact of the statute so far is unclear. Dr. Langenberg said, "The response has been mixed and I think on the whole rather disappointing." The economic climate militates against corporate donations; if there are no profits, there are no taxes, and no incentive to donate. Dr. Darnell recommended that tax incentives would be enhanced if fair market value of equipment were allowed as the tax credit base:

> A recognized, though admittedly partial, solution to the research instrumentation problem in our universities is to permit the expansion of the equipment and donation programs sponsored by industry. DuPont participates in such a program though the dollar value of this aid is relatively small (less than $100 thousand/yr. in fair market value) in comparison to our other aid programs. The lack of a significant tax incentive appears to be a major barrier for most companies to substantially increase this form of aid. The Economic Recovery Tax Act of 1981 provides for a tax credit on donated equipment equal to the book value (initial cost less accumulated depreciation). However, this book value is based on a depreciation to zero value over only three years. The financial incentive for donation of used equipment woudl be significatnly increased if fair market value were allowed as the tax credit base.

Dr. Langenberg added that some firms have not developed plans yet because they are waiting for the Internal Revenue Service (IRS), to issue regulations implementing provisions of the tax act. The NSF Director has prodded the IRS to begin work on the regulations, but without visible results. Dr. Langenberg urged the Office of Science and Technology Policy and the Congress to press the IRS to issue the necessary regulations.

F. Relationship Between NSF and the Proposed Department of Energy Materials Laboratory

The relationship between NSF and the new materials laboratory proposed by the Department of Energy was discussed. Mr. Walgren asked Dr. Knapp what role the NSF had in the Department of Energy's decision to spend $180 million over five years to establish a materials laboratory. Dr. Knapp responded that although the NSF has a materials division, the Department of Energy has a larger budget and does more work than NSF does in the materials sciences. NSF was not consulted about the specific decision. Dr. Knapp said that the two agencies do coordinate--via joint committees--on the topics of high energy physics and nuclear physics research. He hoped that a similar committee structure would be established for materials science--especially as the field develops and it begins to need more large large equipment and national centers in order to eliminate duplication.

G. NSF Relationship to National Technical Information Service

Mr. Walgren was concerned about why NSF does not provide information on research findings to the National Technical Information Service (NTIS), like other agencies. Dr. Knapp said he would try to obtain an answer.

V. NEW MANAGEMENT PLAN FOR THE DIRECTORATE FOR SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

Authorization hearings for the Directorate for Scientific, Technological and International Affairs (STIA), focusing especially on the topic of the reorganization of STIA, were held. Witnesses who testified on this issue included NSF Director Knapp NSF Director and Dr. James Rosser, President of California State University at Los Angeles.

A. Introduction to Congressional Concerns About the New Organization and Management Plan

In his opening statement dealing with STIA, Subcommittee Chairman Walgren expressed concern that the proposed management and organizational changes had far-reaching policy implications:

> The Foundation has proposed a reduction of funding for the STIA overall as a change in policy and mangement in the areas of international cooperative scientific activities, research initiation, and improvment and others . . . . I am most concerned by the policy implications of what is suggested as merely "management" directives.

B. NSF's Description of and Rationale for the Proposed Changes

Dr. Knapp justified the changes as follows. The objective of all NSF research support is to maintain the health of science and engineering in the United States. NSF has used two methods to organize its activities:

(1) in research directorates, organized around disciplines, where the ". . . major emphasis has been on excellence and the production of new knowledge"; and

(2) in programs and activities not organized around a discipline, such as education, international cooperative science, program for minorities and women, and for undergraduate research. The programs have been "generally . . . oriented towards particular institutions, groups or issues and their programmatic content, priorities, budgets are often driven by changes in policy concerns of Administrations and Congresses rather than scientific development." These activities have not been supported and managed by the research directorates, but by STIA or offices attached to the Office of the NSF Director. 1/

Dr. Knapp said that the "dual approach will not best serve the needs of U.S. science and engineering in the years immediately ahead" because there are perceptions that (1) the quality of work is not as good as in the

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1/ According to the NSF Budget Justification Summary to the Congress for Fiscal Year 1984, some budgetary support as well as decision-making responsibility for the following programs will be wholly or partially transferred from STIA to the research directorates: a new subactivity, called Research Initiation and Improvement, which combines the programs previously supported under the Coordinated Agency-Wide Research Activity (CARA) programs, which included: Intergovernmental and Public Service Science and Technology, and the Ethics and Values in Science and Technology program element in the Policy Research and Analysis Subactivity; International Cooperative Research Activities; Visiting Professorships for Women; the Experimental Program to Stimulate Competitive Research; NSF Planning and Evaluation; and the Waterman Award. Several new programs, which would have been managed by STIA, are proposed to be handled by the research directorates. These include the U.S.-India Joint Program; Presidential Young Investigators Research Awards, and Undergraduate College Research Support.

research directorates and (2) some of the programs have not been effective. He said he determined that the responsibilites of the research directorates have been defined too narrowly. He stated that conceptually there should be no separation between research and education of scientists and the research directorates should be responsible for managing STIA's "special programs."

The Director proposed a new management system: "The 'research directorates' must have greater responsibility for evaluating and decisionmaking on proposals that have been handled previously the the directed programs." For certain programs, such as management of international science or participation of women and minorities, the Director said there will be agency-wide coordination by STIA to ensure that goals are being met. Science education, however, would be managed separately. The NSF also plans to establish a tracking system to ensure that adequate resources are being devoted to areas proposed for transfer and to facilitate accountability. However, similar to procedures that have been used in the STIA directorate, special criteria and specially selected peer reviewers would be used so that "funding decisions will be consistent with the special circumstances" surrounding research at different kinds of institutions. At the time of the hearing, the Director said he had asked the NSF Assistant Directors to work out a detailed implmentation plan, which he intends to implement in October 1983, at the beginning of fiscal year 1984.

C. Groups Which Approved Or Acceded to the Proposed Changes

The Director testified that he sought approval for his idea from several important groups. But his statement implied that their responses did not necessarily signify overwhelming agreement:

> I have discussed this shift in management responsibility with the National Science Board, with the Office of Science and Technology Policy, with the Office of Managment and Budget, with three previous NSF Directors, with the chairman of our Committee on Equal Opportunities in Science and Technology, with the Women's Subcommittee of that Committee, with the steering committee of the Director's Advisory Council, and with the Assistant Directors of the Foundation. The responses I have received range from concurrence to enthusiasm.

D. Criticisms of the Proposed Changes

The proposed transfer of funding and management responsiblities from STIA to the research directorates raised a number of issues.

1. Survival of "Special Programs"

In a written question to the NSF, the Subcommittee asked how STIA could continue to coordinate its former programs if it no longer has responsibility for funding, priority-setting, and evaluation. NSF responded, obliquely, that coordination may mean to "cause to act together in a smooth concerted way." NSF responded to another written question about whether program managers would tend to give more attention to the support of basic research activities, rather than the "special programs" to be transferred from STIA, by stating that the "activities being proposed for shift are basic research activities." Many observers, including several of the witnesses, disagreed with this position.

2. The Proposed Transfer of International Cooperative Science Activities

The subcommittee gave considerable attention to the proposed transfer of international science activities to the research directorates. According to NSF, "responsibility for the evaluation and formal recommendations regarding proposals involving international science will rest with the 'research directorates.' The STIA directorate staff will evaluate the international aspects of these proposals. Thus, the final decision will be a joint one." Apparently, this is the only program for which STIA formerly had full responsibility in which STIA staff and research directorate staff will make joint decisions. STIA staff will keep the research directorate staff informed about the international aspects of research and laws; the research directorate staff will be responsible for issues relating to proposed research, but all decisions will be joint.

Subcommittee Chairman Walgren asked whether NSF proposed to cut funding for international science by $5 million pursuant to the budget justification NSF submitted. Director Knapp testified that while it appeared in the budget documents as if funding would be cut, funds merely would be transferred out of STIA to the research directorates to support international activities. However, the Subcommittee Chairman responded that it would be difficult to trace the funding for international science in succeeding years, because there are no separate line-items for international science in the budgets of the directorates. Director Knapp replied that a separate financial tracking system would be instituted.

Dr. Knapp did not respond directly to Mr. Walgren's question about whether the perception was true that less than adequate science is conducted in many international and foreign programs. But, he said that he expected the reorganization to widen " our overall choice of scientific people for the international programs . . . because the research directorate program missions have much wider contact with the entire research in any given discipline than the people who are much narrower, say within the STIA directorate." Dr. Paul Maxwell, a committee staff member, disagreed and questioned NSF's ability to attract more researchers to international programs when, in fact, the international budget per se would be cut 50 percent, which, he said, would probably cause researchers to propose fewer international activities. Dr. Maxwell also asked whether a successful transfer of international science to the research directorates would be unlikely because foreign policy factors are more important than scientific criteria in determining the content and thrust of NSF's international science activities. Dr. Knapp did not answer these questions directly. He responded that if better research were conducted, improved international collaboration and cooperation would be fostered. Others have commented that the new management scheme may benefit scientific cooperation with industrialized countries whose research is compatible with the interests of the research directorates, but may hurt the cooperative science programs with less developed countries, whose research is less important to the research directorates.

E. Approval of the Transfer for Minority Programs, If NSF Makes a Committment To Increase Support for Minority Programs

Dr. James Rosser testified that his university generally did not profit from NSF support programs for minorities because most NSF minority programs were directed toward blacks, while most of the minorities at his school were Hispanic and Asian. Most of the support his school receives for minority science programs comes from two programs run by the National Institutes of Health; that is, the Minority Biomedial Research Support Program (MBRS) and the Minority Access to Research Careers Program (MARC). Additional funds from NSF would be very useful, he said. Several factors in NSF's existing (pre-reorganization of STIA) management structure militate against effective minority science support programs. These are:

- inadequate funding overall;
- use of ambiguous definitions of minority institution, with the implications that some NSF support programs do not meet their congressionally emunciated goals; and
- inadequate attention in the NSF research directorates to the needs of minorities.

He viewed the proposed realignment of STIA as having both disadvantages and advantages, but, on balance, he said, the benefits exceeded the costs. Dr. Rosser outlined the likely costs of the proposed STIA management changes. These are:

- a dilution of effort for minority science support;
- disappearance of effort and funding for minority science programs if there are no specific allocations for these programs in the research directorates;
- lack of uniformity in policies, priorities for, eligibility criteria for, and implementation of programs for minorities from directorate to directorate;
- increase in bureaucracy; and
- "accountability will be distributed and it may be difficult to identify any single office or individual who will take overall responsibility for making decisions and setting policy."

The following are advantages that might flow from the proposed management shift, if NSF increases its commitment to minorities overall:

- increased funding for minority programs, if responsibility for minority programs were spread across all directorates;

- broadening of the number of institutions benefitting from minority programs, if the entire NSF were involved in programs; and

- "integration of minority programs into all of the directorates could be a major step toward providing minorities with acceess to the mainline research programs of the NSF."

He offered the following recommendations to ensure that minority programs were compatible with the proposed changes in STIA:

1. That at least for a reasonable period of time, an office be established directly under the NSF Director with the responsibility for overseeing the development of minority programs in each of the directorates and for monitoring the progress of these programs. This office might also function as a clearinghouse to provide information to assist institutions and individuals in gaining access to programs in the various directorates. If the efforts of this office are successful, the need for it should eventually disappear.
2. That the NSF, concommitant with its implementation of the new management plan, take steps to insure that the directorates give sufficiently high priority to minority programs so that the total resources committed to these programs increase substantially.
3. That consistent eligibility criteria be established that will not exclude institutions that should logically qualify but, rather, will broaden the participation of institutions having significant numbers of minority students.
4. That well-defined and specific performance objectives be formulated to help guide the efforts of each directorate in developing minority programs and that corresponding evaluation criteria be formulated against which the performance of each directorate will be measured for continued funding. In other words, each directorate should be evaluated on the basis of results.
5. That each directorate be required to develop a plan describing how it will develop its minority programs and meet the specified performance objectives and that the Naitonal Science Board then consolidate these plans into an overall plan for the Foundation.
6. And finally, that the National Science Board review annually the performance of the directorates and of the Foundation in meeting the established minority program objectives.

VI. SUPPORT FOR THE BEHAVIORAL AND SOCIAL SCIENCES RESEARCH SUPPORT PROGRAMS

Witnesses who addressed the issue of funding for the behavioral and social sciences were Dr. Thomas Juster, University of Michigan and Dr. Herschel Liebowitz, Pennsylvania State University.

A. Subcommittee Chairman Walgren's Criticisms of the Low Funding Levels for Behavioral and Social Sciences Research

In his opening statement on the issue of funding for behavioral and social research, Congressman Walgren said that NSF earmarked $223.6 million for fiscal year 1984 for the Directorate of Biological, Behavioral and Social Sciences, an increase of $33 million over the fiscal year 1983. Most of the increase was slated to go to the biological sciences areas, and funding proposed for behavioral and social sciences was still 22 percent below the fiscal year 1980 level. ". . . Unfortunately," he said, "despite these increases we still do not see the funding base restored for the behavioral, social, economic, and information sciences despite directives from all of the involved committees of Congress to the contrary." Mr. Walgren was especially concerned about the cuts in behavioral and social sciences because of the tremendous gap in knowledge in these areas. He attributed the Administration's cuts to its "disapproval of 'social engineering' and government involvement in areas that are admittedly controversial." And, in contrast to the perceived Administration position, he illustrated how important the social sciences are:

> . . . Stanford University conducts a program of science re-education for its graduates and particularly many . . . management people; and in that program they have found that although the social sciences are the most controversial at the outset, they are the most valued . . . .

Vivid evidence of the need for more knowledge of human interaction, he said, is seen in the Vietnam Veteran's memorial in Washington and in the requirements for improving productivity.

NSF Director Knapp testified that NSF had increased funding for the behavioral and social sciences as much as possible commensurate with other funding needs. But Mr. Walgren questioned NSF's priority setting methods, and said that funding for the AAEO Directorate was increased 54 percent above the previous level, but that the funding increase for the behavioral and social sciences was much lower. Dr. Knapp responded that the physical sciences needed considerably more instrumentation than the social sciences (an assertion social scientists testifying disagreed with, see below), and that if funding for instrumentation were eliminated the increased funding levels would be equivalent.

1. Questions Regarding Application of Undistributed Funds to the Behavioral and Social Sciences

The Foundation has $4.5 million in undistributed funds left over from the FY 1983 budget allocation, according to Mr. Walgren. He wondered if that money could be allocated to the behavioral and social sciences. Director Knapp said the funds were from the ocean drilling program and that, shortly, NSF would come up with a recommendation to allocate the money, implying that he could not allocate the funds as Mr. Walgren suggested.

B. Criticisms of Cuts by Witnesses

Dr. Thomas Juster opened his statement by citing earlier testimony of Drs. Knapp and Keyworth, who said that the support of basic research was crucial to economic recovery and revitalization of the research base in this country. But, according to Dr. Juster, the 1984 budget request does not support this goal because it emphasizes natural and physical sciences research. More support is needed for the social sciences because "much of our capital stock consists of human skills and not machinery and equipment . . . . In short we depend, as a society, at least as much on advances in the social and behavioral sciences as on those in the physical and natural sciences." Dr. Liebowitz concurred with these statements, adding that the FY 1984 budget attempts to establish a hierachy among the sciences and gives NSF a "partisan mission."

The cuts in funding for behavioral and social research have serious implications for the future of these disciplines, according to Dr. Juster: fewer young students are choosing social sciences as a career and support for young investigators and for high-risk projects by researchers of all ages has been reduced. In addition, contrary to what Dr. Knapp said, social scientists need instrumentation, especially computers, as much as scientists in other disciplines:

> There has been a revolution in social science methods. It is data intensive, computer intensive, and instrument intensive. The needs here are as great as in the natural and physical sciences.

Dr. Juster testified that, "at the University of Michigan, 35 percent of the usage of computers is by social and behavioral scientists in terms of hours of computer time burned up." Congressman Walgren agreed that behavioral and social science research is instrumentation-intensive and recommended that the NSF begin a study to assess the instrumentation needs of all the sciences.

C. Illustrations of Breakthroughs Made By Behavioral and Social Scientists

Both Drs. Juster and Liebowitz gave illustrations of useful breakthroughs made by behavioral and social scientists. According to Dr. Juster, social science research has reversed the stereotyped notion that the "culture of poverty" consists of a permanent underclass. Quite to the contrary, he said, longitudinal (over time) studies have revealed that there is considerable turnover through time, a finding which has massive implications for public policy toward the poor. Dr. Liebowitz's list of the benefits of behavioral research included: (1) interdisciplinary research in experimental psychology and engineering which have dealt with such societal problems as the need to understand human factors in aviation, or which have helped to define the boundaries of other societal problems, such as trying to motivate people to wear seatbelts, and (2) breakthrough findings in such areas as group behavior, conflict resolution, and motivational patterns leading to success in managing large organizations.

D. Recommendations for Needed Research

Dr. Juster testified that the 1984 budget will not accomodate all the data bases that require support, including those dealing with personal savings behavior; measures of organizational behavior; measures which combine economic and oranizational factors; and meaures of well-being in market and non-market economies.

He also listed other areas where measurement research could be enhanced if more funding were available. These included: theory of markets; statistical methods for longitudinal data bases; estimation techniques for macro-economic models; mediation techniques to alleviate overcrowded courts; and longitudinal data bases to describe effective methods of deterrence. He estimated the cost of this and other needed research at $12.5 million.

Several areas of behavioral research would profit from an increase in funding according to Dr. Liebowitz. These include studies in: overeating, drug abuse, smoking, and coping with the wider use of computers.

When asked to prescribe an appropriate level of funding increase, Dr. Juster recommended the $12.5 million he had estimated as the cost of needed measurement and other projects. He said that judgments about funding increases should be made by those outside of the scientific community since scientists would favor their own disciplines. However, several years ago a National Academy of Sciences Committee, dubbed the "Simon Committee" for its chairman, Nobel laureate Herbert Simon, reported that social and behavioral sciences programs are as high in scientific quality as are programs in physical and natural sciences. The implication was that all areas of science should be given equal treatment.

In his printed testimony, Dr. Liebowitz recommended that the Committee insist that competence, rather than political beliefs, should be the chief criterion for selection of a new Assistant Director for the Biological, Behavioral, and Social Sciencess.

VII. SUPPORT FOR INFORMATION SCIENCES RESEARCH

Dr. Joe Wyatt, Chancellor of Vanderbilt University, and chairman of the Advisory Committee to the NSF Division of Information Science and Technology based his testimony, in part, on a report produced in 1982 by the Division, entitled "Research Opportunities in Information Science and Technology," NSF-82-63. The United States is now facing a serious problem, he said, since Japan and Western Europe are outpacing this country in some areas of information sciences and communications technology. He stated that the seriousness of this problem is exacerbated since Japan can develop technology much more easily than the United States and much of Japan's communications technology evolved from basic research supported by the National Science Foundation. This issue, he said is the "'real world war'" that we should be prepared to combat. The Division needs additional funding to support needed research that the private sector will not support. Dr. Wyatt said that when his committee was formed in 1978, it recommended funding at $11 million, but the Division has never received more than one-half that amount. The recommended 1984 level is about $6 million, which will necessitate a reduction in staff from 15 to 9. In answer to a written question submitted by the Committee, NSF said it did not see any problems with this figure:

> Information Science and Technology is an emerging field of research and this level of funding would permit NSF to fund about 50% of proposals received by it. The success ratio in other BBS programs . . . by comparison, is of the order of 20-30%.

A. Research That Warrants Attention

Several research areas warrant priority attention, according to Dr. Wyatt. First, in robotics, more research is needed on the recognition of geometric shapes without human intervention (this requires understanding of human behavior relating to the brain, simplification, categorization of information, and learning). Second, most proposals to the division which have expensive instrumentation costs are not funded, but these areas require increased support. Third, there is a need to assess the behavioral issues that affect the development and use of this new technology. A recent *New York Times* editorial indicated that 95 percent of middle management feels insecure about implementing new technology in the workforce.

B. NSF Involvement in Computer Networks

Congressmen Frederick Boucher and George Brown asked about NSF's involvement with computer networks. Congressman Brown was especially concerned about whether NSF plays a role in providing universities with access to supercomputers via the NSF-supported computer network, CS NET. Dr. Knapp responded that the NSF network links computer facilities in universities funded by NSF. He added that it is a slow system and does not provide access to supercomputers, but generally universities do not need access to highspeed supercomputer facilities. Two other federally-funded supercomputing networks are available to university researchers: the DOD ARPANET and the Department of Energy's magnetic fusion network. Commercial networks, according to Drs. Knapp and Wyatt, also provide access to the capabilities needed. Dr. Wyatt said that while he was at Harvard he served as chairman and chief executive officer of EDUCOM, a national computer network of colleges and universities. This group recommended that the university network use commercially available communications resources, such as ARPANET, TELENET, and TIMENET, rather than special networking facilities. These are used for "access to large collations of data that are very difficult to move" and for "access to large algorithms that are also difficult to move, such as those at the National Center for Atmospheric Research." Dr. Knapp added that NSF has formed a committee to look at the overall problems of computer access for NSF grantees in all areas of science, and that this issue would be the topic of consideration at the May 1983 National Science Board meeting. However, he added, NSF did not have the capability alone to provide the base for a supercomputing support effort; all Federal agencies would have to be involved.

C. Need for Coordination of Information Sciences Research in NSF

In a written question to NSF, the Committee asked

> Would NSF be able to develop a more effective and comprehensive program if the Information Science, Computer Science, and Computer Engineering Division (now located in three directorates--BBS, MPS, and Engineering) were brought together in a new directorate where adequate and coordinated management attention could be given to all programs?

NSF responded that the current "arrangement allows these disciplines to draw and build upon the cognate research taking place in three directorates," and that it preferred this "flexible" approach.

VIII. MISCELLANEOUS ISSUES: TRANSFER OF ENVIRONMENTAL PROTECTION AGENCY RESEARCH TO NSF

During the posture hearings before the full Committee, Congressman Matthew F. McGrath said that it "was recently brought to . . . [his] . . . attention . . . that . . . in the . . . fiscal year 1984 budget submission by the EPA, 50 percent of the funds requested for exploratory research programs will be managed by NSF for contracting out long-term research." He was concerned about whether the Foundation had given sufficient attention to implementing this proposal. Dr. Knapp responded that he had heard the transfer had been "put on hold" and that a draft interagency agreement was being prepared. However, he said "NSF would manage the basic research programs on EPA-like problems if we were asked to do so" and that NSF was prepared to begin managing 40 percent of the program and increasing its management to 100 percent in the next fiscal year if the budget permitted.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

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OFFICE OF THE
DIRECTOR

February 9, 1983

Honorable Don Fuqua
Chairman
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House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

I am writing in response to your letter of October 4, 1982, concerning the National Science Foundation's (NSF) plans for allocating the funds made available to it under Public Law 97-272, the FY 1983 HUD-Independent Agencies Appropriation Act.

As you know, that Act provided a total of $1,092 million for NSF, including appropriations of $1,060 million, $30 million and $2.2 million for Research and Related Activities, Science and Engineering Education, and Special Foreign Currency, respectively. The NSF current plan for FY 1983 is shown in the enclosed table. In making allocations to NSF activities and subactivities, careful consideration was given to the guidance set forth in Congressional reports, as well as to the most promising scientific priorities and opportunities.

For example, $3.0 million above the FY 1983 budget request was added for the behavioral, social, economic and information sciences. Also, approximately $2.0 million will be provided in FY 1983 for engineering research to aid the handicapped. Overall, I believe that NSF has developed a responsive, well-balanced and fiscally sound program within the FY 1983 appropriations.

I look forward to working with you on the Foundation's FY 1984 request.

Sincerely yours,

Edward Knapp

Edward A. Knapp
Director

Enclosure

RECEIVED
FEB 15 1983
COMMITTEE ON SCIENCE
AND TECHNOLOGY

COMPARISON OF FY 1983 CURRENT PLAN WITH FY 1983 REQUEST

	Request	Current Plan	Difference
MPS	$ 298.7	$ 299.6	$ .9
ENG	99.7	100.8	1.1
BBS	186.7	190.4	3.7
AAEO	259.7	259.4	-0.3
ODP	14.0	16.5	2.5
USAP	86.4	82.4	-4.0
STIA	44.0	44.0	-0-
MISIP	3.3	-0-	-3.3
PD&M	63.1	62.4	-0.7
Unallocated Reserve	-0-	4.5	4.5
Subtotal, R&RA	1,055.6	1,060.0	4.4
SEE	15.0	30.0	15.0
SFC	2.2	2.2	-0-
TOTAL, NSF	$1,072.8	$ 1,092.2	19.4

EXPLANATION OF DIFFERENCES

MPS (net increase of $.9 million):

- From $3.0 million in request for possible reprogramming to ODP, $2.25 million reprogrammed to ODP and $.75 million to undistributed reserve.
- From appropriation increase and limitations increase, $3.9 million for high priority research instrumentation including instrumentation for faculty at 2-/4-Year Colleges.

ENG (increase of $1.1 million):

- Added from appropriation increase and limitations availability:
  - $1.1 million added for research instrumentation and the physically handicapped research program.

BBS (net increase of $3.7 million):

- The $3.0 million included in the request for possible reprogramming to ODP was reprogrammed to the undistributed reserve.
- Added from appropriation increase and limitations availability:
  - $3.7 million for research instrumentation, including faculty at 2-/4-Year Colleges and other high priority research areas, e.g., plant sciences.
  - $3.0 million for social/behavioral sciences.

AAEO (net decrease of $.3 million):

- From $3.0 million included in original request, $2.25 million reprogrammed to ODP and $.75 million to undistributed reserve.
- From appropriation increase and limitations availability:
  - $2.7 million for instrumentation, including astronomy and faculty at 2-/4-Year Colleges, and other high priority requirements.

ODP (increase of $2.5 million compared to the budget request but $4.5 million increase compared to the appropriation of $12.0 million):

- $4.5 million reprogrammed per Congressional Committees' approval.

USAP (decrease of $4.0 million):

- Appropriation limitation - Operations Support $4.0 million less than request.

PD&M (net decrease of $.7 million from request):

- $.7 million of request not approved in appropriation.

UNALLOCATED RESERVE (increase of $4.5 million):

- $4.5 million: $3.0 million reprogrammed from BBS and $.75 million each from MPS and AAEO. (Held pending additional program recommendations by the Foundation on Ocean Drilling.)

SEE (increase of $15.0 million):

- $15.0 million added to the request by Appropriations Committees.

COMPARISON OF CARA PROGRAMS
FY 1983 REQUEST AND CURRENT PLAN

	Request	Current Plan
NSF Planning and Evaluation	$ 2,500,000	$ 2,500,000
Visiting Professorships for Women	1,000,000	1,500,000
Minority Research Initiation	2,500,000	2,000,000
Research Improvement in Minority Institutions	2,000,000	2,000,000
Experimental Program to Stimulate Competitive Research	2,500,000	2,500,000
International Council of Scientific Unions	800,000	800,000
TOTAL	$11,300,000	$11,300,000